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SKETCH

OF THE

GEOLOGY OF THE PUNJAB.

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SKETCH OF PUNJAB GEOLOGY.

NOTE.—*The following Sketch of the Geology of the Punjab was kindly prepared by Mr. H. B. Medlicott, then Director of the Geological Survey of India, for insertion in the Punjab Gazetteer. Unforeseen circumstances delayed the publication of the Provincial Volume of the work; but the Sketch as it now stands was in the hands of the Editor in November,* 1883.

SECTION A.—INTRODUCTORY.

Introductory.
Geography dependent on geology.

Geological agencies being so slow in operation when compared with the life or the history of man, it is no wonder that the configuration of the earth's surface or of separate countries has been treated as a fixture, and described from that point of view as geography. This is of course unavoidable when mere portraiture is concerned, as in maps, but it is no longer fitting that in the verbal description of the varied features of the ground surface no mention should be made of their mode of formation and history. Rational geography must therefore introduce geological considerations. Geography, in fact, apart from mere topography, becomes a corollary to geology.

Postulates of geology.

There need be no objection to this suggestion on the score of difficulty; for, the initial postulates of geology being based upon facts of universal experience, the statements involved in such geographical descriptions must be perfectly intelligible to any one, even though at first sight the credibility of them may be questioned. These postulates can be enunciated in the briefest form: geologists affirm that stratified rocks were formed as we now see deposits accumulating by the action of water; while volcanoes (active or extinct) offer an equally safe standard of identification for all the remaining forms of rock; also, that the inequalities of the earth's surface were primarily formed by actual upheavals and depressions, whether in broad areas with little fracture of the rocks, or concentrated along certain lines with intense contortion of the strata. True mountains" belong to this latter kind of disturbance. Actual ases of local upheavals and depressions have been witnessed and measured. Finally, the sculpturing of the raised areas is visibly the result of wear and tear by atmospheric waters.

Main geological regions of India.

The agreement ~~implied~~ by the foregoing statements between geographical and geological features is very decided in the demarcation of main regions; while it becomes rapidly less so as we go nto geological details. For instance, a mountain mass composed of very similar rocks may comprise several distinct formations, but his fact has no significance in the geographical feature; of this here will be abundant examples in the sequel; we have to begin

Introductory.

with the leading features of agreement. India has been separated as regards its rock surface into two great divisions, the peninsular and the extra-peninsular; the great intervening plains forming a third region of comparatively insignificant importance in geological history. The Punjab holds ground in all three divisions.

The Punjab Plains.

A very large proportion of the Punjab lies within the Indo-Gangetic plains, which continue south-westwards through Sind to the Arabian Sea, and south-eastwards through the North-West Provinces, Behar, and Bengal to the Bay of Bengal. In the broad angle thus formed the plains rise gently southwards, through Rájpútána, to the flanks of the Aravali hills which form the north-western region of the peninsular rock area, some small outliers occurring within the Punjab in Delhi and Hissar. Northwards, the plains rise to what may be called their outer margin, where the extra-peninsular rocks rise abruptly into steep and high hills, very rarely having any stragglers within the alluvial area.

The Punjab Mountains.

The peninsular and extra-peninsular regions so well defined by the intervening plains are also distinguished by marked characters peculiar to each area. The peninsula is a great block of land which has through a long lapse of ages undergone only very partial and local disturbance, and all its later sedimentary rocks, including some of high antiquity, are distinctively freshwater or subærial deposits; whereas the extra-peninsular rocks, except the later tertiaries, are marine deposits, and even the newest tertiary beds have everywhere undergone extensive disturbance along regular lines of upheaval. Thus in its present general outlines the whole of the latter region belongs approximately to one and the same age, and is markedly newer than the former. This distinction is clearly betrayed in the fact, already indicated, that the plains' deposits have spread amongst and isolated the worn-down remnants of the Aravali rocks, while they stop short against the continuous lines of upheaval of the extra-peninsular area.

The extra-peninsular mountain region of the Punjab.

With respect to the extra-peninsular area, the Punjab occupies a peculiar position—in the angle where the lines of mountain upheaval undergo complete and abrupt changes of direction. On the north-east the Himalayan axes with a north-westerly trend run very steadily up to the Jhelum; while on the west the axes of the Sulemán maintain a northerly direction up to the Kurram river. In the block between these two dominant systems we find ranges of devious trend in which an east-west course prevails, corresponding t that of the Sufed Koh in Afghánistán; of this group the Sal Range is the best known example.

The non-parallelism of its mountain ranges discussed.

Such total and sudden changes of direction in great lines of contortion, belonging more or less to the same period of disturbance, has been a point of some theoretical difficulty in view of certain hypotheses which would require synchronous disturbances to be in parallel directions. The question can best be noticed here, as it concerns each of the three main divisions of our ground. This feature of direction is nowhere so conspicuous as where its limits are defined along the edge of the great plains, and seems most

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The Aravali Region.
The non-parallelism of its mountain ranges discussed.

probable that the explanation of the difficulty is to be found in the form of the more ancient land of the peninsular area. It is now generally understood that the crushing of strata resulting in the upheaval of mountains is due to tangential pressure in the earth's crust caused by the shrinkage of the interior, so that the unsupported weight is converted by the earth's curvature into horizontal thrust. This may find relief in several ways: by slight warping of the curvature, producing the elevation and depression of large areas; or by slight compacting of the rocks, with local disturbance at many places over a large area; but it is certain that it sometimes settles into great flexures of the strata where most susceptible to compression, and this implies a greater strength of resistance in the adjoining masses, the form of which would thus in a great measure determine the direction of the axes of contortion.

The peninsular rock-system extends beneath the Punjab plains.

The general parallelism of the northern edge of the peninsular area to the Himalayan border along the opposite side of the Gangetic plain gives considerable plausibility to this view, and it is probable that the gneissic rocks of the peninsula extend a long way northwards beneath the plains. The great north-western prolongation of the plains in the Punjab might seem to be more an independent result of the extra-peninsular disturbance, but the only direct evidence brings this feature too into the same relation with the older rock area: for on both sides of the Chenab, at Chiniot and Karāna, only 40 miles from the Salt Range and about 200 miles from the nearest outcrops of the Aravali rocks, some small hills which rise from the plains are composed of quartzites and schists, quite unlike any rock found in the Salt Range or anywhere in the ground bordering the plains on that side, but of the same character as those forming the mass of the Aravali hills. There is confirmatory evidence in the Salt Range itself: everywhere else the newer tertiary rocks appear at the edge of the plains, but here there is a long section of very old formations turned up to view, and in composition and arrangement they suggest coastal conditions in this position. It thus seems presumable that the plains are for the most part underlaid by rocks of the peninsular area, or at least that such rocks as do occur are not deeply affected by the disturbance that has upheaved the extra-peninsular rocks.

The foregoing remarks will suffice for a general introduction to the ground. We may now give some particulars of the separate regions; and it will be convenient to dispose first of the most ancient ground, forming the Aravali region and extending into the Delhi and Hissar districts.

SECTION B.—THE ARAVALI REGION.

Limits of the Aravali Region.

The Arvali region is the most distinctly separable factor of the peninsular rock area. It is the remains of a very ancient mountain system having a north-east trend, and therefore tangential as it were to that area at its north-west extremity, its boundary here being very sharply defined by the scarp of the Vindhyan plateau

The Salt Range and its Western Extension.

Changes of level consequent upon transfer of matter from the mountains to the plains disturbing local equilibrium.

that inference; and it is the obvious explanation of the constantly observed fact of depression in deltas. Borings in the delta of the Ganges at Calcutta have discovered land surfaces far below the present sea level. Now these conditions occur in a very concentrated form along the fringe of the Himalayan border. An enormous amount of detritus is annually swept down from the mountains, a relatively large proportion of it being from the softer rocks of the Sub-Himalayan hills; and a relatively large proportion of that detritus is deposited in the upper marginal region of the plains. It thus becomes a matter of certainty that depression to an unknown extent has taken place in this latter area. This view considerably modifies the inference to be drawn regarding the lower beds in the Ambala boring if based on the supposition of extensive elevation and erosion. The probability would now seem to be that the boring did not reach beds of Siwálik age. It is evident that these later conclusions regarding the underground relations of the plains deposits render more difficult than ever any speculation as to the position or depth of an artesian source, although by no means shaking the probability that such sources occur there.

SECTION D.—THE SALT RANGE AND ITS WESTERN EXTENSION.*

The three divisions of the Salt Range.

Their geological formation.

The Salt Range, both cis and trans-Indus, possesses geological features peculiarly its own. It presents a complex arrangement of strata affording sections almost entirely different eastwards towards the Jhelum from those westward near the Indus, and both differing considerably from the sections presented by the trans-Indus extension of the range. This triple or tripartite development of the rocks may be compendiously expressed as follows:—

Comparative Table of Formations.
(NATURAL ORDER).

	TRANS-JHELUM.	CIS-INDUS.	TRANS-INDUS.
		QUARTERNARY.	
Alluvial and sub-recent.	Rainwash and superficial deposits.	The same	The same.
Post Tertiary ...	Conglomerates and clays. *(unconformity*	The same ... .. *throughout)*.	The same.
CAINOZOIC.			
Pliocene ...	UPPER SIWALIK. Conglomerates, drab and pink clays with bones and reptilian remains.	UPPER SIWALIK. The same.	UPPER SIWALIK. The same.
	LOWER SIWALIK. Gray sandstone and red clays with bones.	LOWER SIWALIK. The same.	LOWER SIWALIK. Gray sandstones with bones, clays subordinate, seldom red.
Miocene ...	NAHAN OR MURREE BEDS Greenish gray sandstones, some red clays, reptilian remains and fossil wood.	NAHAN OR MURREE BEDS. The same slightly represented.	NAHAN OR MURREE BEDS. The same scarcely represented southwards.
Eocene ...	NUMMULITIC LIMESTONE Large gastropods, bivalves, echinoderms & alveolina, &c., &c (locally absent).	NUMMULITIC LIMESTONE The same.	Olive clays, pale sandstones, conglomerate of limestone overlying—Pale limestone (locally absent).
Eruptive ...	... ...	... ...	Traps, ashes, &c., in Subáthu beds of Thall on Kurram river.

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* This sketch is by Mr. Wynne. For his more detailed report on the Salt Range, see Memoirs of Geological Survey of India, Vols. XI, XIV, XVII.

The Salt Range and its Western Extension.
Their geological formation.

Comparative Table of Formations—(Continued).
(NATURAL ORDER.)

	TRANS-JHELUM.	CIS-INDUS.	TRANS-INDUS.
MESOZOIC.			
Cretaceous ...	OLIVE GROUP sandstones and shales chiefly *Terebratulæ* and bivalves obscure.	Absent or unrecognisable.	Whitish sandstones, upper part of a dark earthy zone containing a neocomian ammonite.
Jurassic ...	Absent. ...	VARIEGATED GROUP red and white and variegated sandstones, &c.	Thin limestones and shales under dark earthy zone. Ammonites, bivalves, &c.
		Ammonites? Belemnites, &c.	Variegated soft sandstones and clays, obscure plants.
Trias ..	Pseudomorphic salt crystal zone, red flaggy sandstones, red clays, perhaps triassic.	Gray limestones, calcareous sandstones, gray marls, ceratites, &c.	Gray limestones, thick marls, dolomites, &c., ceratites.
PALÆOZOIC.			
Carboniferous ...	Unknown ...	Gray and magnesian limestone, calcareous sandstone, shales, *Productæ*, *spiriferæ*, *Bellerrophon*, *goniatites*, *&c*, *&c*.	The same.
Infra Carboniferous.	Absent or on the horizon of a group of Magnesian sandstones?	Speckled sandstones, red and lavender clay.	Red or purple boulder clays, sandstones and gypsum and thick dolomite.
Silurian ...	Black clunchy shales, &c., with Obolus or Sephonotreta.	Absent	Absent.
	Purple sandstone ...	Absent locally ..	Purple sandstone (? same)
	Salt marl, salt gypsum and red marl	The same ...	The same at Kalabagh only.
Eruptive ...	A few exposures in upper part of red marl.	Nil.	Nil.

It will be seen from this list that the rocks embrace a very considerable series representing palæozoic, mesozoic and cainozoic as well as more recent deposits. Throughout the whole up to the bottom of the post-tertiary beds there is a singular absence of marked unconformity, trifling indications of discordance having only been observed locally between the jurassic and cretaceous horizons trans-Indus, and again at the local base of the tertiary rocks, mainly of newer tertiary aspect, where they are in junction with triassic beds in the Kiri Khasor and Nala Keh ranges, trans-Indus.

Speculation as to the geological history of the system.

There is much inequality of deposition on the eocene horizon, and this has been held by some to mark a great period of disturbance and arrested deposition; but while the possibility of discordance entirely invisible may always exist, the absence of its usually prominent signs over so large a region is a fact not easily set aside. It has also been urged that there is represented in the Salt Range a sort of transition between the rocks of the Peninsular and those of the Himalayan region, from a marine facies westward to a freshwater or continental state of things eastward. Variety certainly is present; but where so much of the older eastern Salt Range series is quite unfossiliferous, it is scarcely fair to presume that if organic remains were present they would be other than marine, especially as the single ancient *Obolus*, or whatever it may eventually be called, which has been found there, is certainly marine. Leaving these points to hardy speculators, it will be more useful

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The Aravali Region.

Limits of the Aravali Region.

from Fatehpur Sikri (near Agra) to Chitor, and thence by the scarp of the Malwa trappean plateau to the Narbada. Its southern skirts are covered by newer rocks in Guzerat and Cutch. On the west and north, towards the Punjab, it can be said to have no boundary, presenting only straggling outliers of rock more or less encompassed by the alluvium of the rivers and the blown sands of the desert. We have seen reason to suppose that if these were removed, rocks of the Aravali region would be found to extend in the Punjab nearly up to the boundary of the extra-peninsular area. The low range of hills from which the name of the region is taken, and which is probably the remnant of the axis of the original system of upheaval, is chiefly developed between Palampur and Ajmer, beyond which place its continuity is very broken, the alluvium sweeping right through it at many points, as where the Sámbhar salt lake lies right in the run of the axis. The most northerly outliers on the line of the range occur near Hissar and Rohtak, touching the Jumna at Delhi. A notice of this region is therefore required in a sketch of the geology of the Punjab.

The Aravali and Delhi rock-systems.

The rocks forming the range itself belong, so far as is known, to two series to which the names Aravali and Delhi have been given. The former is the older of the two, and consists, within the range and for some width on either side, of crystalline schists in great variety, with crystalline limestone and some quartzite. In many parts the schists are largely associated with gneiss, and all are folded together in complicated contortions having the prevailing north-north-east strike of the range. Granitic intrusions occur extensively in and near the range; while at a distance from it the metamorphic action diminishes, and the Aravali series consists chiefly of slates more or less schistose, as for instance to the east of Deoli. The Delhi series is best exposed in the Beána and the Alwar hills, from which latter it extends up to Delhi. It is principally composed of quartzites, locally conglomeratic with some partings of schists, and locally with strong bands of contemporaneous basic trap. This series occurs also within the range, where the highest ridges are thought to be formed of Delhi (or Alwar) quartzite, and where it also is locally affected by the intrusive granite.

Age of the Aravali system.

Lower limit.

It will be understood that stratified rocks may give evidence of two very different periods, that of their deposition or formation and that of their subsequent disturbance. In the latter sense both of these rock series belong to the Aravali system, and give the lower limit for its date. The two series are however very distinct, and are found at many places in totally unconformable contact; each is, moreover, identifiable with extra-Aravali peninsular rocks still unaffected by the Aravali disturbance, thus showing the limit of that disturbance and its relation in time to the rocks of the peninsular area generally. The Aravali series has been fairly identified, at least in part, with the rocks that had been previously described as the Gwalior series, to the east of the Vindhyan plateau. Here the upper Vindhyans rest upon a deeply-eroded surface of the Gwalior rocks; but these rest in original undisturbed superposition upon the gneiss of Bundelkhand. Again, the Delhi series has

The Aravali Region.

Age of the Aravali system.
Lower limit.

been traced to the south-west through Tonk and west of Chitor, into connection with some sandstones south-west of Nímach (Neemuch), where they show very little disturbance and are overlaid with slight unconformity by lower Vindhyan strata. On the west in this locality these sandstones rest upon an older gneiss, presumably of about the same age as the Bundelkhand gneiss, and this mass seems to have protected the sandstones here from the compression and metamorphism of the Aravali system. These facts show clearly that the Aravali gneiss, crystalline schists, and granite, and the causes to which the metamorphism and upheaval were due, are all of later date than some of the unaltered rocks of the peninsular area.

The gneiss of the Aravali Region.

If we adhere to the geographical outline as above indicated for the Aravali region, the older gneiss that has just been mentioned south-west of Nímach as probably of the same age as the Bundelkhand rock would have to be introduced as a third rock series within this region. It is not yet settled whether some of the many other outcrops of gneiss may not belong to the older kind.

The Vindhyan system.

Yet a fourth rock series has to be mentioned as belonging to the peninsular area in the Aravali region; and this is the Vindhyan series. For a long distance on the south-east the edge of the Vindhyan plateau has been taken as the boundary of the Aravali region. That boundary is for the most part a faulted one, and the fracture has certainly occurred on the lines of the Aravali disturbance; although even here it can be shown that this was a secondary effect produced long after the contortion and upheaval of the Aravali rocks, for on the north-west side of the fault there are some Vindhyan outliers resting flatly upon the vertical Aravali schists. Over the broad area between this boundary and the axis of the range all further traces of the Vindhyan rocks have been removed; but on the west side, and within a short distance of the present axial range, rocks that can with much certainty be identified as upper Vindhyan cover a considerable area, to within a few miles of Jesalmir. The average base of the formation seems about level with the present surface of the plains, and at many places the Vindhyan sandstone is seen resting flatly upon the contorted gneiss and schists of the Aravali series. Thus, in the Vindhyans (which are at least of palæozoic age), we have an upper limit for the date of the Aravali upheaval; and we can say that it must have occurred at quite a remote time before the Vindhyan period, for the range had then already been denuded to something like its present dimensions.

Age of the Aravali system.
Upper limit.

Intrusion of the extra-peninsular system.

We have still to notice some other rocks that occur within the outside limits conjecturally assigned for the Aravali region as defined by non-participation in the great extra-peninsular upheavals. About Jesalmir and west of it there occur low ridges of jurassic and nummulitic rocks belonging to the extra-peninsular formations. From the comparatively little disturbance they exhibit, it is probable that they are overlapping extensions on the margin of the peninsular area, and that Aravali rocks occur at no great depth beneath them.

The Salt Range and its Western Extension.

Nature of the evidence: and difficulty of the enquiry into the structure of the region.

to indicate briefly tangible facts regarding the rocks and structure of the region.

In all the southern acclivities, in the profound rocky gorges by which its escarpment is intersected, and over its summit crags and northern sides, there is no want of sectional or other evidence from which to ascertain the composition of these Salt Range mountains from the banks of the Jhelum to the somewhat indefinite frontier of the Afghan uplands to the west. The chaotic state of the southern escarpment, however, requires extreme caution amongst its subsided masses, to disentangle the original arrangement of the beds.

This confusion appears to be equally due to the presence of the great saline deposits forming the base of the series, to the alternate recurrence of friable and more solid rocks, and to the peculiar climatic conditions of the country, subject to extremes of drought and wet and wind at distant intervals, and not unfrequently a desert cold-producing frost at night, though the heat in the day-time may have been very great; and action of torrents and all the meteoric forces which can abrode rocks and disintegrate mountains are the necessary consequences of such a state of things.

Saline series.

The lowest and oldest rock known in the Range is the great rock-salt deposit; but at a distance of some 35 miles to the southward, presumably older sub-crystalline and slaty beds occur in the Karána hills, according to Fleming and Theobald * * (Jour., As. Soc., Bengal, Vols. XXII and XXIII).

The geological history of the salt is as obscure as is usually the case; and, as in other places, it is found to be overlaid by massive beds of gypsum; indeed the red marly rock which marks the position of these minerals is itself largely gypseous and often saline. Although the thickness of the salt, where most accurately known, as at the Mayo mines, is enormous, the very conditions under which it may probably have been accumulated in detached basins preclude the inference that it extends everywhere beneath the Range as one vast sheet. The local disturbances too may naturally point to its extensive removal by percolation of fresh water. Notwithstanding this, however, its presence at numerous localities almost along the whole southern foot of the mountains for 116 miles, and often with thick outcrops, leaves little necessity to qualify the assertion that the supply is practically inexhaustible.

Outturn and quality of salt.

The annual records show that the outturn of salt from the Range equals in maunds 12 to 13 lacs, producing a revenue of 40 lacs of rupees, or £400,000 sterling yearly.

Potassium salt.

The salt is of reddish or whitish colour in thick bands of great purity, alternating with other thick bands of more impure and earthy character, called by the miners *kuller*. Between some of the strata at Khewra, Mayo mines, a stratum of potassium salt was found, having a thickness of a few feet. From more recent workings it appears the deposit had a lenticular shape, and was limited in size to some 600 superficial feet as estimated by Dr. Warth, formerly Collector at these mines. Its presence indicates the possibility that other deposits of this valuable salt might be found if sought for. The salt in its crude form is a mixture of

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sylvine, or that form of potassium chloride which is now the principal commercial source of potash, with kieserite (magnesium sulphate) and common salt. (*See* Manual of Geology of India, Vol. III, page 501; Records, Geological Survey of India, Vol. VII, page 64).

Bitumen.

The rock-salt of the range, though not known to be itself bituminous, is associated with layers of highly bituminous shale in the over-lying gypsum at Khewra.

Volcanic tufa.

Near the place where this shale occurs, and in a few other situations on apparently the same horizon in the eastern part of the range, there is an interbedded mass of volcanic tufa, porphyritic by the presence of numerous small crystalline needles of a semi-transparent mineral-like decomposed actinolite. Together with this are some feet of lavender-coloured clay, occasionally containing talcose veins; it is used as soap by the natives.

Saponaceous clay.

Trans-Indus salt.

A notice of the neighbouring salt region of Kohat may appropriately be given here for the sake of comparison. The last known exposures of the Salt Range palæozoic salt occur at Kálábágh on the Indus; and for some nine miles up the Lún nala in a north by west direction there are others at intervals. But further into the Kohat district in this direction another kind of rock-salt occurs in great quantity, and in numerous exposures, for a distance of 40 miles amongst the tertiary hills on both sides of the Teri Toi river. The general character of this Kohat salt is a more or less crystalline mass of different tints of gray when not quite transparent, with numerous transparent blotches. In some places it is dark, smelling strongly of petroleum. A few bands only contain sufficient dark silty clay to render it unsaleable. No such impure earthy bands as separate the Khewra salt beds occur throughout the district. The salt is overlaid by white and gray gypsum and gray or greenish gypseous clays, generally much confused as to stratification, and in this resembling the Salt Range marls, but the aspect and colour of the gypseous strata is as distinct as possible in the two regions. The gypsum varies in thickness and occupies large areas over the axes of anticlinal curves. Associated with it are some layers of alum shale, and it is sometimes black and bituminous like the salt.

Alum.

Overlying the gypsum is a thick deposit of blood-red clay having a few sandy layers, and near the top a double band of coarse purple, sometimes conglomeratic sandstone containing a few fragments of fossil bones, and this is succeeded by the eocene limestone.

The Kohat salt more recent than the Jhelum salt.

In all the numerous exposures of the Kohat salt-field no older rock than the salt has been discovered, and both it and the gypsum as a rule follow the curves of the adjacent newer limestone. Rock-salt may be of almost any age, but this apparent conformity and the utter absence of all proof that the beds are older lead to the inference that this salt, gypsum, &c., are of nummulitic age or immediately antecedent thereto, the supposition being less violent than the assumption that this salt series is contemporaneous with that of the Salt Range, while all the intervening formations from the infra-silurian sandstones to the jurassic or cretaceous inclusive should have disappeared by gradual thinning out. It is difficult

SECTION C.—THE PLAINS.

The Plains.
Sources of the Punjab sands.

Blown sand occupies no inconsiderable place in the rock formations of the Punjab. The Province has a "Little Desert" of its own in the Sind Ságar Doáb; and large tracts elsewhere are in a similar condition. There is no sea here to keep up the supply for these wind-deposits; but other sources are not wanting in the ever-renewed sand banks of the subsided rivers, and in the boundless barren hill region to westwards where the "sand-blast" must operate extensively as a denuding agent, supplying dust to be swept on by the wind and deposited elsewhere. The geological influence of the wind as a rock-producer has been very little studied or taken into account, but the importance of it cannot be doubted. We may recommend it as an interesting line of research to residents in the Punjab. The investigation should be historical as well as dynamical, for it is surely presumable that the present state of things has come about well within the human period and to a great extent since the earliest historical times. It is not to be believed that plains of fertile ground traversed by copious streams and in a sub-tropical climate were left by nature unclothed with vegetation. In the remote hills on both sides forest still survives, simply because it is out of reach of the spoiler. The process of spoliation is familiar to any one who has travelled in the jungles of India. Want or the petty profit of the moment is all that is thought of, no matter what the waste; and one may see square miles of withered poles of magnificent forest trees that have been ringed for the few ounces of gum to be extracted from each. At least a few years ago it was so, before the Forest Department came to the rescue.

When steep ground is thus uncovered it becomes rapidly denuded of its soil, and the bare rock remains. On the level ground, when an undue proportion of it is taken up for cultivation, an immense area is left bare under the baking summer sun after the spring crops are cut, to become so deeply desiccated and heated that much atmospheric moisture is repelled and never reaches the ground. In this way the climate becomes gradually changed at an accelerating pace, for each step makes recovery more difficult, and thus large tracts of north-western India have become waste, and the struggle against outraged nature for the rest becomes continually harder.

Formation of the Punjab plains.

From the condition of the great rivers it is at once apparent that the plains are most recent deposits; and that they have been, and are being, formed by these very rivers. The Punjab lies altogether in the western basin of the Indo-Gangetic plains, its eastern boundary coinciding with the watershed between the very flat basins of the Indus and Ganges systems; and that boundary is the river Jumna. On any longitudinal section of the plains taken east and west between the Siwálik hills on the north and Delhi (where the Jumna touches Aravali rocks) the highest level is on the banks of the Jumna. Now, that a river should run on a watershed is proof positive that it has made the ground it flows upon. This is the normal condition of a depositing river, as most

The Plains. Formation of the Punjab plains.

familiarly known in deltaic regions. By periodical overflow the river gradually raises its banks and at the same time its bed, and so finally runs on a broad ridge of its own construction. If left to itself it will finally break into the lower ground on either side through some hitherto small channel of overflow, and so take up a new course. A noted example of this occurred early in this century in north-eastern India, when the Brahmaputra deserted its old bed through the Maimensingh district and adopted a new channel 60 miles to the west, the change originating near the point of the Garo hills. In the Punjab much evidence has been brought forward to prove that within historical times the Sutlej followed a very different course from its debouch at Rúpar.* No geologist will question that all the great Himalayan rivers must have undergone like changes within very recent geological times.

North and south slope of the Punjab plains.

In other features of configuration the plains correspond to the mode of formation suggested by the cross-section at the rivers. All the streams, big and little, issue from their more or less steep and confined channels in the hills variously charged with detritus in time of flood. As they can immediately expand in the open country their carrying power is rapidly reduced, and much of the heavier and coarser detritus becomes deposited at the edge of the plains, only the finer sediment being carried to a distance. In this way a surface is formed having at top a considerable slope (more than 50 feet in a mile), which diminishes rapidly at first and then very gradually towards the final point of discharge. This is the form of the surface of the plains of India from the foot of the hills to the sea, their slopes corresponding with those of the rivers; and in extent their distribution corresponds with that of the water-power issuing from the adjoining hills. In this respect the Himalayan rivers greatly preponderate, and have accordingly laid down the greater part of the plains to near the northern edge of the peninsular area. The level of the Jumna bank at the edge of the Siwáliks is about 1,060 feet. The lowest point of the summit level of the plains may be taken up on the Jumna bank at Delhi, where it is about 700 feet, and followed to the west-by-north into the Punjab a little south of Rohtak and of Hissar, being defined by the line where the spill from the Aravali meets that from the Himalayas, and the surface rising both to north and south. Between Hissar and Sirsa this 700 feet contour-line bifurcates, going to north-north-west along the Himalayan spill to south of Lahore, while the other branch curves to the south-west along the Aravali spill to the west of Bikanír.

Erosion of the present valleys of the Punjab rivers. The Bar and western plains.

Any observant traveller in Upper India would at once notice that the foregoing description of the plains is not at all points correct. It has been thus given from the geological point of view, and in order the better to indicate the immediately actual state of the surface. The facts that have been given regarding the outline are correct, and also the inferences to be drawn from them; but the Jumna and the other great rivers do not now, even in the most abnormal floods, rise to the level of those banks asserted to have been

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* Calcutta Review, July, 1874.

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Erosion of the present valleys of the Punjab rivers. The Bar and western plains.

formed by their overflow. To account for this it might at first be suggested that modern floods are less than those of yore; but observation makes the very opposite suggestion, for it seems that, although more or less in the same position as when they gave form to the adjoining lands, the rivers have since then eroded broad valleys, to as much as 100 feet deep, in their former deposits, thus producing the characteristic features of the western plains of the Punjab. These valleys are known as *khádirs*, as distinguished from the *bángars* or *bár* lands, the uplands of the intervening *doábs* (land between two confluent streams). Various causes might be assigned for this effect, such as a change of levels, giving increased fall and therefore greater denuding power to the rivers. Action of this kind has probably had local effect, but we are bound to enquire whether the chief cause may not be one that is known to have operated, namely, the wholesale removal of forest vegetation. The effects of this change have been already called into account for the present desert condition of large tracts in this region; and another well known result of the same cause is that now under consideration. When rain falls upon a forest-clothed country, a very large part of it clings about the vegetation or is absorbed by the open soil at its roots. In the present state of this country the rainy season bursts upon a bare land baked hard by the fierce sun of the dry season, the water runs off the ground in torrents, and the channels, big and little, are scoured by floods that could never arise in such a region in its natural condition as unchanged by man. Thus the apparent discrepancy between the actual state of the rivers and the assertion that they have formed the land they flow through is converted into a confirmation of that view, for the effect corresponds in degree and in time with the known cause assigned for it. The uplands, which form the great *bár* prairies of the Punjab, are probably the remains of the general surface of the plains as it stood in prehistoric times.

The Thal.

The Thal, or desert formation often found capping the Bar lands, and which occupies so great an area in the Sind Ságar Doáb, is purely a wind-deposit, a continuous spread of sand-dunes. The apparent capriciousness of its distribution may be largely due to the unknown drift of the atmospheric currents; or it may be affected by unobserved obstructions, for once started sand-dunes tend to reproduce themselves, each one forming a back-water in which another may gather.*

The area of closed drainage. Eastern plains.

Further illustrations of the same conditions are found in the eastern Punjab. Although the banks of the Jumna in its course from north to south form the summit level of the plains, and no drainage enters the Jumna from the west in this part of its course, yet it is in one sense misleading to speak of the right bank of this river as the watershed, for there is an immense tract of country to the west—almost the whole area between the Jumna and the Sutlej—from which no drainage ever enters the sea or other water

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* Mr. Medlicott writes elsewhere: "They may even grow backwards against the wind, a check to which is the immediate cause of their formation; and thus the distant Salt Range may possibly have been the basin of the Sind Ságar Thal."

The Plains.
The area of closed drainage.
Eastern plains.

basin. At the head, along the base of the Siwáliks, that area is 75 miles wide: but as the Sutlej immediately on leaving its gorge takes a course to north of west up to its confluence with the Beas near Sobraon, the area in question widens rapidly, so that on a parallel through Delhi the Jumna and Sutlej are 230 miles apart. Two considerable streams, the Markanda and the Ghaggar, and many minor ones, leave the hills within this area and flow straight away sea-wards; but they are nearly expended by evaporation and soakage before reaching the south boundary of the Punjab, and entirely disappear in the desert of Bikanír. They were once probably tributaries of the Sutlej when it formerly held a more direct southerly course; or more certainly of the Jumna if ever its waters, as is extremely probable, flowed to the western sea. Here then we can be certain that the whole work done by these rivers is expended within the area. For "time out of mind" none of the detritus from the hills for a length of at least 60 miles has left this ground, yet the surface here has not been essentially changed since the Jumna ceased to be the chief depositor. We are thus again led to the inference that this cannot have been very long ago.

The rivers have only recently ceased to deposit and begun to erode,

Saline nature of the well water in the area of closed drainage.

There is another feature of this case that requires notice. Modern primers of geography tell us what is the almost inevitable result of a drainage area having no outlet—that the enclosed basin becomes saline from the continuous evaporation of drainage water, which always contains some salt in solution. The only thing that can prevent this result is a sufficient underground percolation, which would have the same purifying effect as a surface outlet. It is clear that a similar result must ensue when the drainage water is dissipated without collecting in a basin, only the product will be more diffused. Now this effect is well marked in this peculiar area; all the southern part of it, where the final evaporation takes place, is extensively impregnated with saline matter, so that good drinking water is scarce. At Bhiwani, south of Hissar, the ground water was found to be brackish to a depth of 400 feet. This area of closed drainage forms nearly a third of the Punjab plains, the remainder being occupied in succession from east to west by the Jullundhur, the Bári, the Rechna, the Jetch, and the Sind Ságar doábs, with the narrow tract known as the Deraját between the Indus and the Sulemán range. To all these the foregoing general considerations are applicable.

Submontane tract.
Absence of the *Tarai* zone.

There remains to be noticed but one point of contrast with the eastern or Gangetic area of this continuous formation. The zone so well known in the latter region as the *Tarai* is not distinctively represented west of the Jumna. It is a broad belt on the outer edge of the gravel slopes everywhere found next the hills. This coarse deposit absorbs water copiously along the foot of the hills, and so much of this as does not penetrate to the deep water-bearing strata finds its way to the surface again along the outer edge of the gravel beds, where also an abrupt change of slope occurs. In this way there is formed the second zone of peculiarly swampy ground known as the *Tarai*, the inner gravelly slope being known as the *Bhábar*, or forest zone. Although the gravel zone is of

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course found everywhere, and equally of course absorbs its full share of what water is spilt upon it, the *Tarai* is scarcely represented in the west. This may be partly due to a smaller rainfall, and so to little or no surplus escaping permanent underground percolation; but to a considerable extent it is due to the cause that has already been detected in so many ways, the destruction of the forest vegetation. It is not so very long since the climate and vegetation must have been very different from what they are now, when the Mogal emperors used to hunt wild elephant and rhinoceros on the borders of the lower hills of Jammu. The destruction of forest has, however, been much more extensive here than to eastwards, with the result that a greatly increased burden of detritus from the soft tertiary rocks of the lower hills is thrown upon the streams before entering the area of deposition. A great quantity of it is soon left behind, obliterating the conditions of slope required to produce a *Tarai* zone, the corresponding position in the Punjab being taken up by accumulations of sand which there is not water-power to carry further. For a description of the conditions under notice, reference may be made to Mr. B. H. Baden-Powell's account of the *chohs,* or sandy-bedded torrents from the Siwáliks in the Hoshiárpur district.*

The Tarai only recently disappeared.

The underlying deposits of the Punjab plains.

We have still to notice the depth or thickness of these deposits as a point of practical as well as of speculative interest. The surface deposits belong everywhere, as we have seen, to the human period. In a cutting near the head of the eastern Jumna canal, Colonel Cautley dug out a fossil town.† Everything below is concealed. It would seem that near the "outer" margin of the plains on the Himalayan side, a very close limit to the age of any beds conformably underlying the recent alluvium should be assignable: for the topmost beds of the Siwálik series, of latest pliocene, if not of pleistocene age, are tilted up vertically; yet they are indistinguishable in composition and texture from the actual river deposits. Disturbance of such magnitude must, one would think, have extended to some distance south of these outcrops, and thus have involved total unconformity of the Siwáliks with any beds that are still undisturbed within a considerable distance. If this were so, it would follow that any beds conformably underlying the surface deposits in the neighbourhood of the Himalayan margin must be long post-Siwálik. But, as will presently be shown, the disturbance to which the upheaval of the Siwálik is due probably extended to only a small distance from that margin.

Far from the mountains, anywhere within the protecting influence of the underlying hard rocks of the peninsula, it is evident from what has been said that the plains deposits might be in unbroken sequence with the whole tertiary system; and on this "inner" border of the plains, even at the small depth to which observation has access, beds having some small comparative antiquity occur in close relation with the surface deposits. In the lower

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* Selections from Records of Punjab Government, new series, No. XV, 1879. *See also* Records of Geological Survey of India, Vol. XIV, p. 228.

† Journal Asiatic Society, Bengal, III, p. 43, 1834.

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reaches of the Jumna, between Agra and Allahabad, where the river has eroded its channel to a depth of 100 feet below the level of the adjoining plains, bones of extinct forms having some affinities with those procured from the upper Siwálik strata have been found in perfectly undisturbed clays.

Formation of tertiary fluviatile deposits in the plains area.

Any surmise upon the underground features of the plains deposits can only be derived from the view formed of antecedent conditions as indicated by the features of adjoining areas. On the peninsular side there is good evidence to show that, so far back as in immediately pretertiary time, the drainage flowed from the south towards what is now the Gangetic basin: the whole northern scarp of the Vindhyan plateau existed at that time in approximately its present position. The Deccan trap poured over that scarp on to the gneissic area of lower Bundelkhand. How far it may have flowed over the low ground in that direction it would be impossible to say; on the plateau it does not seem to have reached so far north as Gwalior. The total absence of any remnant of tertiary rocks on this border of the peninsula suggests that it was then out of the reach of deposition rather than that all such deposits have been since removed; but it would seem pretty certain that this drainage basin was part of that in which the eocene rocks of the Himalayan border were laid down. Only the lower stage of that series is marine; and the muddy character of these beds, contrasting with the clear limestone of the same age in the western Punjab, suggests estuarine conditions requiring a southern bank far to the north of the present south boundary of the plains, and of course also a limiting land in the actual Himalayan area. Already in nummulitic time these marine bottom-beds became mixed with and soon permanently replaced by others of distinctively Sub-Himalayan characters, consisting of fluviatile deposits with terrestrial and freshwater fossils; and these conditions have lasted throughout the Siwálik epoch to the present day, for as has been said the top Siwálik strata seen at many places in the Punjab are absolutely indistinguishable from those of the plains. These middle and upper tertiary fluviatile deposits were independent of the sea level and would have spread over the whole basin according to its contour, and equally to the south in the valleys of the northern slopes of the peninsular area now concealed beneath the plains. From the foregoing observations it would appear that the Sub-Himalayan eocene marine basin was probably a narrow one; but that the supervening upper tertiary fluviatile deposits may have stretched southwards to an indefinite distance.

Effect of the upheaval which raised the Siwáliks upon the underlying deposits of the plains.

To the foregoing consideration of the original conditions of the basin there must be added what can be said regarding the Himalayan disturbance as affecting the floor, and therefore the whole condition, of the plains deposits. The extreme unconformity already mentioned as occurring between the horizontal plains deposits and the vertical Siwáliks along the Himalayan border does undoubtedly establish an immense lapse of time (as reckoned in historical periods) between the two. But the inference as to how far this condition of unconformity extends beneath the plains

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Effect of the upheaval which raised the Siwáliks upon the underlying deposits of the plains.

to the south of the actual boundary depends upon the view taken of the process of disturbance. It is difficult to resist the *primâ facie* impression from the sight of an immense thickness of stratified rock turned up on end that great violence must have attended such results, and hence that the effects must have extended to far beyond the point where such intensity is exhibited. It was upon such natural impressions that the cataclysmal theories of the early geologists were founded. In the present case, the plausible supposition from such a point of view would be that an elevation of the Himalayan area coincident with the contortions of the Siwálik strata had first resulted in a great valley of erosion from the mountains to the sea, forming a clean-swept basin for the deposits which now form the plains.

Practical importance of the question.

To give meaning to this seemingly useless discussion it may be well to point out that it forms the only rational approach to the practical question often asked—where in the plains and at what depth would there be a prospect of success for an artesian boring. If the supposition just noticed might be counted upon, a very favourable answer could be given to this question. The base of the deposits would then be everywhere within reach; that base would generally consist of coarser materials, such as would form a capacious water-stratum; and it would be in continuous connexion with the present upper zone of gravel beds at the foot of the hills, where copious absorption of water occurs.

Siwálik upheaval probably very limited in its effects.

Careful observation and reflection are, however, against that *primâ facie* supposition. It will be shown that before the disturbance of the Siwálik rocks (*i.e.*, during the Siwálik period) the Himalayan rivers, great and small, flowed just where they now do in the mountains; so that there is nothing to support the supposition that any great elevation or violent movement of any kind accompanied the disturbance of the Siwálik rocks; for they probably were tilted up so slowly that the main rivers could *pari passu* erode their gorges across the rising strata. Another fact of corresponding import is found in the form taken by the Siwálik strata under disturbance. The *dúns*, or longitudinal valleys occurring so constantly inside the Siwálik ranges, are generally formed of the topmost Siwálik strata in a more or less horizontal condition, rising by a gradual increase of dip to form the range outside the *dún*, while on the inner side they either abut abruptly against the rocks of the inner range, or else are bent up sharply to form that range. Such a feature strongly suggests the probability that the final limit of the disturbance may be no less abruptly marked; so that beyond the extreme verge of the vertical Siwálik strata these same strata may have remained permanently in their original gentle slope of deposition, and would thus be in conformable sequence with the most recent deposits of the plains within a very short distance of the hills. It is independently intelligible that the slow compressing force to which the bending of the strata and the consequent rise of the hills were due would expend itself to the utmost on each flexure before giving rise to a new one.

Such a process would of course involve great erosion of the Siwálik strata in the immediate region of upheaval; and there is

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abundant evidence of this, not only in the river gorges and the deep ravines of the minor streams, but along the whole outer edge of the hills, where, as a rule, the uppermost gravel beds of the plains rest upon the edges of low Siwálik strata near the axis of the flexure, the whole of the outer and steeper side of which has been removed. Under the supposed conditions of disturbance this denudation would not have reached far; so that within a short distance there might be completely conformable sequence between the Siwálik deposits and those of the actual plains.

Artesian boring at Ambala.

One important direct observation has been made upon the underground constitution of the plains, in the boring for an artesian spring at Ambala, to a depth of 700 feet. No gravel bed or other water stratum was met with, and the boring ended in stiff clay. If this section could be taken as representative, it would be conclusive evidence against the supposition of these deposits lying in a simple post-Siwálik basin of erosion; for the bottom of such a basin must at Ambala be within a much less depth than 700 feet, and the basal beds in such a basin must as a rule be coarse, porous, and water bearing. It is easy to explain a possible exception to this rule; and Ambala is just in the position where such an exception would be most likely to occur. It is about 20 miles from the foot of the hills, and this is beyond the distance to which gravel is now swept by the small streams and the rain-wash on the steeper slopes near the hills. It is only within the range of the great rivers, in the deeper parts of the supposed basin of erosion, that coarse deposits must occur somewhere in almost every section, especially at or near the base; and in river-formed deposits such as these, the range of the great rivers embraces in time more or less the whole area. Ambala, about midway between the Jumna and the Sutlej, and so near the hills, is just in the position most likely to escape that influence, as the whole growth of deposits might be directly from the hills, or by overflow of finer sediment from the main rivers. In this way there might be nothing there to mark the bottom of the basin or surface of erosion in so small a section as that given by a boring; and thus the passage from the recent plains deposits into beds of such similar composition as are those of the upper Siwáliks would not be noticed. It can, however, be affirmed that the boring did not reach beds that had undergone any considerable disturbance, for the frequency of alternation of beds in the lower part of the boring was as great as in the upper part, whereas a very moderate tilting of the lower beds would have given a perceptible apparent thickening of the several strata passed through by a vertical boring.

Inconclusive nature of the results.

Changes of level consequent upon transfer of matter from the mountains to the plains disturbing local equilibrium.

There is yet to be taken into account a consideration of great weight in this discussion. It was long ago suggested by Herschell, in seeking for a prime mover of the forces by which crust movements are effected, that the familiar process of denudation by the continual removal of matter from steep elevated tracts and the deposition of it in adjoining low ground evidently disturbs the equilibrium of strain beneath those areas, causing a tendency to elevation in the former and to depression in the latter. Recent researches upon the nature of the earth's rigidity entirely confirm

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Extinction of the lower Himalayan region a structural feature.

The change is altogether structural, and not due to secondary causes such as denudation. The strike of the rocks on both sides of the tertiary boundary conforms to it along its bend northwards, showing it to be an aboriginal feature of the Himalayan elevation. There is ample corroborative evidence of this view in the main range itself. In the gorge of the Sutlej above Wangtu the massively eruptive granitic rocks in the axis of the range, as everywhere observed to the east, are still in force, and pass north-westwards into the mountains of Waziri Rupi; but on the western side of this massif, in the deep Kulu valley cut by the Beas right across the axis of the main range, no such rocks have been found. The ground has not been closely examined; but it is certain that the axial intrusive rocks can be but very feebly represented, if at all. The flexures and fractures involved in such a mountain range are so great that their total extinction in so sudden a manner would be matter of surprise; and in fact the great range does from here split up into three minor ranges, each with its gneissic axis, but all of which become absolutely extinct within the basin of the Jhelam. The southernmost of these is the Dháola Dhár range overhanging the Kángra valley, a revival of the same granitic rocks directly on the prolongation of the great Himalayan chain. But here the tertiary boundary is found close at the base of this axial range, within two miles of the granitic rocks. It is this immediate contiguity of comparatively low (2,500 feet) undulating fertile ground with a lofty (15,000 feet) precipitous mountain range that constitutes the peculiar beauty of the Kángra valley.

Fourfold division of the ground.

The foregoing outline of the leading features suggests at once a fourfold division of the geological description: the sub-Himalayan tertiary zone; the lower Himalayas; the axial rocks; and the Tibetan area.

Sub-Himalayan tertiary region how produced.

The name sub-Himalaya is primarily an orographical term, used to denote the lower hills on the border of the mountain area. Such a gradation of elevation is in the first place a result of the elevatory process itself, in which there is a general tendency to a line of maximum effect in a more or less central position. This result is further wrought out, and would to a great extent be independently produced, by the second agency of hill formation, the wearing action of atmospheric waters to which all the detail of surface configuration is due. Drainage must flow outwards from the crest of elevation, and deepen as it goes, thus increasing the effects of erosion in the outer zones. Finally, the conditions of the ground generally lend themselves to the completion of this feature: in a simply upraised stratified mass the topmost beds must in time undergo complete removal from the higher parts, and be reduced to a zone of outcrops at the margin of the area; and as they are the newest and least consolidated part of the whole mass, they are specially liable to disintegrate. Still with a regular sequence of formations there would be an equable gradation of elevation, and the separation of a border zone of lower hills would be more or less arbitrary. Such is not the case however with the sub-Himalayan zone; the change is abrupt and very decided. This is due to several causes, the first of

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Partial pre-tertiary elevation.

which may be noticed here; it is that below the tertiary series there is a great break in the sequence of stratified rocks, the next oldest being much older and much harder, so that the contrasting effects of denudation on the contiguous masses is very marked.

This tertiary series is "sub-Himalayan" in another and a more intrinsic sense—that of having been deposited at the foot of the Himalaya, and out of Himalayan *debris*, as is quite demonstrable for the major portion of the series and more or less so for the whole. To this statement we may at once confront another—that the Himalayan mountains were formed in tertiary times: unequivocal evidence of which is found in the facts that the very latest of these tertiary rocks have undergone extreme disturbance, and that tertiary rocks of marine origin are found at great elevation in the central Himalayas. It is in the elucidation of such apparent contradictions that the origin of the mountains is to be traced out. We have as yet only made a beginning in that direction, the ground is so difficult of access and so much of it is absolutely closed against observers; but it is already plain that the Himalayas were not made in a day or all at once.

Composition of the tertiary series.

The sub-Himalayan series is of enormous thickness, aggregating from 15,000 to 20,000 feet; yet throughout it there is a remarkable sameness in the character of the deposits. The prevailing rock is a massive pepper-and-salt sandstone, exactly like the sub-Alpine tertiary rock known to Swiss geologists as molasse. In its freshest form at the top of series, when very little consolidated, it is undistinguishable from the sand deposited in the beds of the great Himalayan rivers. In the lower part of the series it has become a very firm rock, often of dark purplish colour. With the sandstone there are locally associated strong beds of clay. In the upper horizons, even when turned up vertically, these are undistinguishable from the brown clays of the plains deposits; while the lower beds assume generally deep red tints. Besides the sandstones and clays there are locally enormous accumulations of conglomerates; they always prevail at the top of the local sections, but whether these separate bands are, or not, all of the same age is one of the many crucial questions that remain to be answered.

Derivation rom Himalayan ground

It is through these conglomerates, the materials of which can be specifically recognised, that the most distinct evidence is afforded of the local derivation of these deposits. In the neighbourhood of the great Himalayan torrents the upper tertiary conglomerates are in prodigious force, and are made up of large boulders and pebbles, precisely such as now occur in the beds of these torrents as they issue from the mountains; whereas in the intervening ground between the great rivers the corresponding beds are often largely made up of clays, and such conglomerates as do occur are formed of *debris* of the adjoining ridges, sometimes of the older tertiary sandstones. It is thus plain that at that time the boundary of the mountains was approximately the same as now, and that their features have not been seriously disturbed by the forces which have turned up on end such vast masses of the later tertiary strata.

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Original confusion of horizons.

determined. A provisional list of them is given by Colonel Cautley in his Memoir in the Geological Transactions, 2nd series, Vol. V, and quoted in Falconer's Palæontological Memoirs, Vol. I, page 35. Although the original Siwálik range is that east of the Jumna, outside the Dehra Dún, no fossils are recorded from it except those (just mentioned as having been lost) from the bottom clays at the mouth of the Kálawála pass; yet the west Jumna continuation of what is now taken as geologically the same range was the ground most prolific of fossils. A brief notice of this puzzle will illustrate the problems that occur throughout this region. The west Jumna continuation of the Siwálik range is not strictly in line with that east of the river, being partly in *echelon* to the south; and the rocks are on the whole very different; coarse conglomerate and sandstone are almost the only rocks in the eastern ridge, while in the western hills clays abound. For all these reasons, and because of the provisional identification of the Náhan and the Kálawála fossils, Colonel Cautley and his colleagues never supposed the rocks of the hills on opposite sides of the river to be on the same horizon. He had taken no account of the break in the sequence at the abrupt junction south of Náhan; that striking feature, which cannot but have been seen, seems to have escaped notice altogether, and the section to have been taken as an ascending one throughout, thus making the Náhan beds newer than those of the outer hills. Accordingly Colonel Cautley accounted for the absence of the fossiliferous beds east of the Jumna by their non-upheaval in that direction.

Probable explanation.

Although this view of the relative ages of the two zones cannot for a moment be entertained, the supposition of the east Jumna Siwáliks belonging to the Náhan group, and being quite distinct from the west Jumna Siwáliks, might plausibly be maintained; and it would at once remove the apparent difficulty of the contrast in composition between the adjoining portions of the same range. There are cross-faults and dips in the dividing gorge of the Jumna that would easily lend themselves to such an interpretation. Accepting the identification of the top beds at Náhan with the bottom beds of the Kálawála pass, we should then only have to say that all the overlying strata of the eastern section had been removed at Náhan, and that all the underlying beds of Náhan are still below the ground on the south side of the eastern Siwálik range. But this is not really the simplest view to take; and by the law of parsimony we are bound to take the simplest view until a clearly better one is offered. There is a manifest explanation of that primary difficulty of the contrast between the rocks to west and east of the Jumna under the supposition of their being contemporaneous. The gorge of this river through the Siwáliks is a long way to the west of its debouch from the mountains near Kálsi; so it seems that when the Siwálik upheaval set in the river found the easiest course to be to pass completely round the great banks of conglomerate it had accumulated in front of its mountain gorge. This would fully explain its present position in the Siwálik range between contemporary beds of very different deposits; and it is quite

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Probable explanation.

intelligible that mammalian remains should not occur in coarse "fan" accumulations, and yet be common enough in tranquil inundation deposits close by. The cross-faults and dips now found in the gorge would naturally occur between masses so differently made up. It is usual in such cases to assign the fault as the inducing cause of the river gorge, but in this case the opposite is more likely; it is quite certain the river was thereabouts before the cracks were started; and it is quite probable that the initial erosion of the gorge helped to determine the position of the fractures. We may still provisionally accept Colonel Cautleys' unauthoritative identification of Náhan beds with bottom Siwálik beds, and so consider the former group as in part lower Siwálik. It would be impossible at present to attempt any closer correlation.

Change of the leading structural features.

The change that occurs in the sub-Himalayan zone west of the Simla area, in connection with the suppression of the lower Himalayan region, may be best illustrated by showing what becomes of the two leading structural features which we have seen to characterise that zone on the south margin of the Simla area. The Náhan-Siwálik and the Náhan-Sirmur boundaries, the latter being the "main boundary" of the tertiaries with the old rocks, are continuous throughout the whole region to the east, and almost constantly present the same structural characters, the newer rocks dipping steeply towards and apparently passing under the older. To the west, before reaching the Sutlej, the Náhan-Siwálik boundary, or at least the feature which is apparently continuous with it, declares itself as a faulted anticlinal flexure with steep divergent dips. Within a few miles beyond the deep gorge of the Sutlej above Bubhor this fault and the steep ridge along it die out, and the upper conglomerate beds sweep round the termination of the anticlinal into the valley on the north of the Bubhor ridge, the core of which is formed of lower Náhan beds. This particular ridge and outcrop of Náhan rocks thus becomes wholly extinct shortly after entering the Kángra district. Something very similar occurs along the Náhan-Sirmur, or main boundary. Where it crosses the Sutlej, north of Bilaspur, its direction is nearly due north. Within five miles to the south, east of Bilaspur, the limestone is at the boundary: then the Subáthú nummulitic beds take its place, and steadily higher beds appear along this inner side of the junction, until the feature becomes lost beneath newer tertiary beds which sweep across it into connection with the end of an anticlinal flexure in the Sirmur zone.

Leading structural features of the western area.

The change of direction which is so marked in the boundaries of the Sirmur zone and in the strike of the rocks within it, coinciding with the terminal edge of the lower Himalayan area, is not noticeable in the features of the newer tertiary area. The Náhan ridge above Bubhor at the Sutlej has very nearly the same north-westerly strike as the Siwálik range east of the Jumna. This divergence of the boundaries produces of course a great widening of the Náhan zone as so far described. At Nálagarh it is ten miles wide, formed chiefly of repeated complicated foldings of the deep red and purple clays and sandstone of the lower tertiary type.

The Salt Range and its Western Extension.

to conceive of conditions which would admit of such a series tranquilly surviving through all the changes of eight or nine vast geological periods belonging to palæozoic and mesozoic epochs; while the geographical distance from one or more of these frequently widespreading if detached formations appears hardly sufficient to account for the absence of them all.

Extent of the trans-Indus Salt beds.

This rock-salt occupies a very prominent place in some of the sections. In the Bahadur Khel anticlinal it may be continuously traced either uncovered or slightly concealed for a distance of about eight miles, having a width sometimes exceeding a quarter of a mile and an estimated thickness at one place of more than 1,000 feet. It is exposed along the valley of a small river sometimes forming hills 200 feet in height, almost entirely composed of bare salt beds. This is probably one of the largest rock-salt exposures in the world, and it occurs at but a small and narrow part of one of the elongated salt tracts containing numerous other large exposures of the mineral.

The average revenue from the nine quarry workings open when the country was examined amounted to Rs. 56,290 annually (roughly about £5,000), the cost of the salt, exclusive of miners' charges, being from 2 to 4 annas per maund, as compared with the 3 rupees 1 anna levied in the Salt Range for the same weight.

Purple sandstone.

To return to the Salt Range series: the saline group of that region is immediately overlaid by an unfossiliferous thick mass of dull purple sandstones, traceable with diminishing thickness as far westward as the neighbourhood of Sakesar, the culminating peak of the range cis-Indus, with a height of over 5,000 feet above the sea. A very similar sort of purple sandstone reappears far to the west by south, near the further extremity of the Kirí Khasor ridge, and is there also associated with gypseous rocks, but the exposures are too few to prove its identity. The purple sandstones work well for building purposes, as may be seen in the monument composed of it which has been erected on the battle-field of Chillianwala, and their massive scarps are conspicuous in most of the southern cliffs of the eastern part of the range.

Obolus zone.

It is here immediately succeeded by a dark gray or blackish shaly and clunchy zone, containing in a few localities many fairly preserved forms of an *Obolus* or *Siphonotreta* as determined by Dr. Stoliczka; hence the containing rock and all below it have been assumed to be of not later than Silurian age. These dark-coloured shales accompany the purple sandstone to the westward nearly as far as the later group is recognised, but slowly split up and lose their definite east Salt Range aspect.

Magnesian sandstone.

They are overlaid by two different groups of the series. In the east they are succeeded by one of its most characteristically separate zones, that of the magnesian sandstone, a pale, hard, compact rock, bearing ripple marks and some fucoidal impressions, but no determinable fossils; a rock that from its strength shows prominently in the cliff-sections of this eastern part of the range.

Speckled sandstone.

Further west the *Obolus* beds are as closely succeeded by a thick group of whitish and speckled unfossiliferous sandstones with occasional red bands or dark boulder clays to the westward, full of

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crystalline rounded masses. Pale lavender-coloured clays commonly form its upper part, the group appearing to overlap the attenuated western termination of the magnesian sandstone.

Salt-pseudomorph zone.

Where this appears to take place in the cliffs about Makrach, the next sectionally succeeding group to the magnesian sandstone disappears likewise from the series. It is composed of red, pale, and variegated sandstones, clays and shales frequently abounding in pseudomorphic impressions of the cubical and hopper-shaped crystals of common salt. Its age cannot be fixed for want of organisms; but it has been referred to the triassic period as a mere surmise, though from its colour and arenaceous or earthy aspect it might equally claim to represent the jurassic beds to the west. Where the last group ends there commences to enter the series, as if upon the same or an intervening horizon, the earthy fringe of a mass of limestones, often magnesian shales, sandstones, and occasionally conglomerates, passing into thinner bedded limestones with thick gray clays above. This new accession gains steadily in thickness and importance westward, limestones predominate, and replacing the harder bands of the east give to many of the western cliffs and undercliffs their craggy aspect. The lower part of these limestones, &c., abounds in carboniferous fossils of the well known British kinds, while the upper portion furnishes quantities of *Ceratites* and other triassic forms. The two life zones representing Palæozoic and Mesozoic time, here uniting to form one physical and structural group, accompany each other from where the ceratite band is first distinctly recognised somewhat west of the Sungle-waan, in all the further exposures of the carboniferous and triassic zone, on towards the Indus, where both are lost and confused, but re-appear together in the Kálábágh mountains, and are largely exposed in the Khasor range as well as in the vicinity of the hill station of Sheikh Budin trans-Indus.

Carboniferous and triassic limestones, &c.

Jurassic.

In direct succession to this limestone belt westward come the variegated red and white sandstone clays and yellowish or gray limestones of the jurassic formation. They are first recognised in the grand glens and gorges southwards of Sakesar, and continue prominent in all the immediately cis and trans-Indus sections of any depth except those of the neighbourhood of Isa Khel, and of the Kirí Khasor ridge till near its south-west termination.

Like almost every other group of the country the jurassic beds change, and the mixed calcareous and arenaceous character they exhibit eastwards assumes in the most westerly and intermediate exposures a much more definite double aspect, the red and white and variegated beds forming the lower part of the series and the yellowish and gray calcareous layers being grouped together above. The thickness of the formation too increases, but does not prevent the total or almost entire disappearance of the whole group for a long distance in the Kirí Khasor ridge, where a striking case occurs of the prevailing tendency to overlap in all the stratigraphic arrangements of the country.

In the easterly parts of this formation the fossils are more obscure or scarce than in the trans-Indus localities, but there is an interesting record of the discovery of well-preserved fossil plants

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Himalayan District—Tertiaries.

Original discovery of lower and upper tertiary groups.

The first thing to be done is to classify these rocks. This process will indeed reveal nearly all we know about them, for in geological classification composition counts for little, the structural conditions, involving relations of age, being all-important. The beginning of a classification was made many years ago by independent observers: Major Vicary found some fossils at Subáthú which were determined to be of nummulitic (eocene) age; and the early engineers (Baker, Durand, Cautley) of the Jumna canals brought to light the upper tertiary fossils of the outer hills. A magnificent collection of vertebrate remains was made by Colonel Cautley, and in great part described by Dr. Falconer; and since then the name Siwálik has been famous in geological annals as denoting a richly fossiliferous group of tertiary rocks at the base of the Himalaya. None of these explorers made any observation worth mentioning on the structural features of the rocks, so all the geological work proper remained to be done, though of course it was a great advantage to begin the investigation with two well determined horizons.

Tertiary outlier in lower Himalayan region.

Any attentive reader who knows these hills will have met with a check in the last paragraph, at the mention of tertiary rocks at Subáthú, knowing as he should that this hill station is not orographically in the sub-Himalayan zone. This departure from the normal state of things as previously sketched is one of the great advantages already alluded to as peculiar to this Simla area owing to its partially terminal position in the Himalayan system. Not only are the principal rocks of the lower Himalayan less disturbed and less altered, and therefore under better conditions for observation, here than anywhere to the east; but we also find here, between the Jumna and the Sutlej, the only remnant of lower tertiary strata as yet observed in the lower Himalayan region, with the exception of one small outlier on the ridge east of Rikikes where the Ganges debouches from the mountains. Within the sub-Himalayan zone proper east of the Sutlej the lower tertiary (nummulitic) beds have nowhere been found, much less the actual base of the series; so that but for this remnant on the border of the Simla area we should know nothing of the original relations of the tertiary series to the older rocks of the mountains, and such a gap in Himalayan history would have been irreparable.

Original relations.

By "original relations" we of course understand the condition of the older rocks when the next deposits began to be formed, and to explain this it is necessary to have some acquaintance with the former. The newest rock of the older formations in the Simla area is the Krol limestone, forming the picturesque mountains on three sides of the Solan rest-house on the Simla road. Below the limestone there is an immense but unknown thickness of strata, in which shaly flaggy slates form the prevailing type. All these stratified rocks are now greatly crumpled up and deeply eroded, but it is certain that formerly they were quite flat and that the limestone extended indefinitely beyond the limits to which it is now reduced. The age of the Krol limestone has not been fixed, for want of fossils; but the latest age assigned for it is the triassic, the lowest system of the secondary era. This would make a great break in the sequence

Himalayan District—Tertiaries.
Steep abrupt junctions.

between it and the lowest tertiary strata; but this fact is quite evident independently.

The commonest mode of junction between the tertiaries and the old rocks is one of abrupt abutting contact. Thus in the narrow ridge crossed on the Simla road between Dharampur and Solan the south face is of tertiary sandstone and the north face of the Simla slates. Had the formation of stratified rocks started upon an even bottom and gone on uninterruptedly, such a junction as this could only take place by "faulting," *i.e.*, a fracture on either side of which upward or downward movement took place, bringing beds of different ages into juxtaposition. There is a natural proclivity in observers to interpret such junctions from that partially normal point of view; but it is plain that any natural basin of deposition formed by the depression of a land surface must present many steep slopes and scarps along which the new deposits would originally abut against the old. Any one with the smallest geological discernment must perceive the very different significance of these two modes of junction, so similar in outward appearance. The worst of it is that the distinction of them in the field is most difficult, on account of the rarity of finding a contact section well exposed; and even when such a natural section is found a conclusive criterion may be wanting. Very commonly the appearances would be deceptive, especially in rocks that had undergone subsequent compression, as is so markedly the case here; for a surface of contact between rocks of very dissimilar texture would be a locus of crushing and of friction or even of faulting, whereby the original character of the junction would be completely disguised and reversed. This technical point has been explained at some length, because the interpretation of boundaries is of paramount importance in geology, and prominently so in cases of mountain structure, as will be illustrated further on.

Crucial section at Subáthú: pre-tertiary Himalayan elevation.

Some few basal junctions of the tertiary series have been described, an important one being at Subáthú itself, which stands partly on nummulitic rocks and partly on the slates. Between the bazar and the parade ground there is a steep synclinal fold of the strata, a characteristic ferruginous bottom bed of the tertiary series cropping up on both sides and quite parallel with the bedding of the underlying slates. Down the steep valley to the north-west the flexure can be traced continuously, the same beds being in contact throughout. Two very important inferences may be drawn from this section. First, that the old rocks must have been deeply denuded, probably as a land surface, before the nummulitic period. The total absence (so far as known) of intermediate formations between trias and tertiary in the outer Himalaya would in itself suggest such a fact, unless we were to presume that all had been subsequently removed; but this Subáthú section *proves* that for an indefinite pre-tertiary time this portion at least of the lower Himalaya had been undergoing denudation. The precise horizon of the slates at the contact has not been made out, but more or less of these strata and all the Krol limestone had been removed. An extensive pre-tertiary Himalayan elevation is thus established for this portion of the ground.

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near the Bak ravine, not far from Musakel, by Dr. Fleming, the locality of which, however, has not been re-discovered. In the localities near Kálábágh and Sheikh Budin numbers of belemnites, ammonites, with gastropodous and bivalve shells, have been found; and in some places fossil tree trunks are so numerous as to have been collected and used as coal on the Indus river steamers.

Cretaceous.

The next or cretaceous group of the series is represented in recognisable form only in the easterly and westerly portions of the district, and in these places by rocks of very different appearance. To the west, trans-Indus, thick soft yellow sandstones at the base of the eocene with few traces of fossils overlying a thick mass of dark clunchy shales, containing a neocomian ammonite, partly represent the cretaceous horizon; but the sandstone seems physically more connected with the overlying eocene, and the dark shale contains jurassic fossils in its lower part. In the eastern half of the cis-Indus Salt Range the cretaceous formation is represented by a certain dark olive group of sandstones, flags, and shales or clays with peculiar shaly boulder beds of semi-trappean look, with great rounded (and in one case glacially striated) blocks of crystalline rocks: with these there are a few deep red earthy and flaggy bands. Fossils are scarce here also; some obscure plants, fish teeth, bivalves, and a determinable terebratula, where the zone approaches the carboniferous limits, being the principal palæontological evidence obtainable.

These olive beds are supposed to represent a more largely developed mass of somewhat similar character beyond the Dera Gh//ázi Khan frontier; and they seem much more nearly connected with the overlying eocene than with the groups on which they rest, the downward succession being to the eastward into the red flaggy and earthy salt-pseudomorph zone, further west into the speckled sandstone, and near the central part of the Salt Range proper, into the fringing earthy and calcareous rocks of the great carboniferous limestone; while the relation to the overlying eocene, or in its absence the succeeding tertiary bands, remains constant. This clearly proves, notwithstanding the apparent parallelism, the importance of the break represented by the overlapping succession.

Eocene.

Throughout the Salt Range region and its extensions in a westerly direction the series above described is generally covered by the widely though fugitively distributed white nummulitic limestone. In some localities, however, it is totally absent. Sometimes it is perhaps represented by a few layers of conglomerate formed of its own limestone pebbles, but usually it forms a massive cap to all the underlying rocks, varying in thickness up to 800 or 1,000 feet. A certain uniformity of aspect prevails, but this is subject to some local variation, more in the association of other beds with the limestone than in the mutability of the rock itself.

Coal.

Thus, in the eastern part of the Salt Range, where the group in places dwindles to a few feet, it is found to include layers of whitish friable sandstone below alternating with red bands, and to contain amongst these layers a band of coal and coaly shale of varying quantity and quality. It is generally pyritous, but sometimes would afford excellent fuel if the cost of extraction were not

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The Salt Range and its Western Extension.

Coal.

likely to interfere with its value. The deposit is rather extensive, appearing in numerous places from the eastern to the western regions of the range and even beyond the Indus; but the thickness of the useful part of the coaly band seldom exceeds from one to three feet. To the east the carbonaceous band forms a basal member of the eocene group, but in the opposite direction (in the Bak ravine) it lies nearly in the middle of the limestones, and the sandy basal portion of the group is in this region almost suppressed. Another somewhat distinctive member of the lower nummulitic layers is a sort of hematitic breccia. This also occurs at more than one horizon further west, and indeed very closely resembles other ferruginous brecciated bands occurring locally in the carboniferous and jurassic formations.

Limestones.

The main mass of the limestones is of whitish or pale yellow colour, sometimes crowded with nummulites or alveolina, and sometimes containing very large ill-preserved casts of echinoderms, bivalves, and gastropods. Its uppermost layers in the east Salt Range are of mingled calcareous arenaceous and argillaceous character, amongst which or intervening between them and the stronger limestone is a conglomeratic layer formed of hard limestone and cherty nodules containing nummulites.

Far to the westward, trans-Indus, somewhat similar conglomeratic bands occur in the lower part of the groups as well as above: in the former case associated with the yellowish white friable and more massive sandstones which here seem to link the eocene and cretaceous horizons, while those conglomeratic layers which occur near the upper limits of the eocene groups are associated with gray and greenish shaly clays not unfrequently present in the Subáthú group.

The last of the nummulitic limestone of the Salt Range region is seen in the Maidan range trans-Indus north of the river Kurram, where some of its thickest exposures occur. It is there covered by the anticlinal folds of the newer tertiary rocks, and where it should reappear in the southern sections only bands of conglomerate containing nummulitic or alveolina limestone pebbles are met with.

Kohat eocene.

To the northward of this country however, in the Kohat district, where the prevailing newer tertiary beds are pinched into anticlinal and synclinal folds corresponding with the hill and valley structure of the region, the nummulitic limestone is frequently exposed, forming the interiors of several ellipsoids, and resting generally upon a zone of deep red clay which immediately overlies the gypseous upper portion of the local saline group.

The nummulitic limestones here are generally thinner as a group than in the Salt Range. They are often crowded with alveolina, nummulites, pelecypoda, gastropods, &c., and contain frequently deep yellow magnesian looking bands, and often appear to be intercalated with the adjacent red and greenish sandy beds of Dugshai or Murree character, but the intensity of the folding the rocks have undergone renders it almost equally probable the appearance is due, as it is certainly in some cases, to contortion.

In the westerly portion of some of these ellipsoids the eocene limestones are closely associated with greenish clays like those in

Himalayan District—Tertiaries. Did not involve contortion here.

The second point established by the Subáthú section is equally important as regards the mode of that disturbance. When the nummulitic deposits took place at Subáthú the old slates there must still have been approximately horizontal, for the strata of both formations coincide. It is thus shown that little or none of the special disturbance now characterising the Himalayan region had then taken effect in this position, so that the previous elevation of this area must have been of the kind known as "continental." For the study of the difficult question of mountain formation, such points as this are of great importance; where evidence is so complicated and obscure, and inferences are accordingly more or less conjectural, any fixed point in the enquiry is very precious.

Probable original limit of basin.

The older tertiary strata here seem never to have got level with the top of the Krol limestone, which probably formed scarped plateau islands in the nummulitic sea or estuary. The conditions would further suggest that for the lowest tertiary rocks, as already shown for the upper part of the series, the northern limit of deposition was not far from the present north boundary. The whole tertiary outlier on the edge of the outer Himalaya, like the small section at Subáthú, is supported on the older rocks, which can be seen beneath the nummulitic beds at many points along the outer boundary. To the north-west, at the Sutlej, the outlier passes into a zone that must appropriately be considered as fully belonging to the sub-Himalayan region, and in which the lower beds become rapidly depressed out of sight; while to the south-east, before reaching the Jumna, it becomes extinct by denudation along a ridge, thus directly illustrating the general easterly increase of the elevatory action in early tertiary time.

Subáthú, Dagshai, and Kasauli groups: Sirmur series.

Only marine nummulitic deposits have so far been mentioned in connection with the lower tertiaries of Subáthú, and these lowest beds are known as the Subáthú group; the prevailing rock is a crumbling yellowish brown clay with some bands of earthy limestone in which the fossils are principally found. The thickness is very variable owing to inequalities in the floor of deposition: in the little section already described at Subáthú there may not be more than 100 feet of the bottom beds, while in the deep valley to the south, and elsewhere, the group must be nearly 1,000 feet thick. It passes upwards transitionally, by interstratification, into rocks of the normal sub-Himalayan type, thick red clays and strong gray and purplish sandstone; these are well exposed in the Dagshai hill, and this name has been adopted for this portion of the series. In the highest beds sandstone almost exclusively prevails, as in the ridge at Kasauli, which name has been given to this upper division. In a fine greenish shaly band at Kasauli numerous fossil leaves have been found indicating the proximity of a sub-tropical forest. The thickness of these upper freshwater deposits may be about 1,500 feet. Thus the rocks of lower tertiary outlier form a closely connected and complete little series to which the local name Sirmur has been given for convenience of distinction, from the Native State in which a large portion of the outlier occurs. Within the series a most complete change takes place in the facies of the deposits, from exclusively muddy beds with marine fossils into a

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Himalayan District— Tertiaries.
Subáthú, Dagshai, and Kasauli groups: Sirmur series.

prevailing sandstone formation in which the only remains are terrestrial. The change took place most gradually, apparently by the filling up of an estuarine basin and the consequent exclusion of marine by fluviatile deposits; the latter being of the type that henceforth obtained exclusively throughout the sub-Himalayan period. Fossils are very scarce, and without them any more precise sub-division of the series would be impracticable; but no doubt it represents a long lapse of time, during which the growth of the Himalaya had steadily progressed.

Middle tertiary; Náhan group.

Having now got some idea of this Sirmur series at the base of the tertiary system, and of the Siwáliks at its upper limit, we may endeavour to fill the gap between them; even a partial equivalence of those two has never been suggested, but such a relation in part has been maintained for each with reference to an intermediate group of rocks. In the far north-west generally, and even in Kángra locally, there is apparently continuous transitional sequence throughout the whole tertiary system, and any divisions to be attempted there can only be of the approximate kind already indicated in the Sirmur series; but east of the Sutlej along the whole lower Himalayan border there is a sharp abutting boundary (wherever the contact has been observed) between the Siwáliks proper and an inner band of more or less similar rocks lying at the very foot of the mountains, the two being generally separated by the longitudinal valleys known as *dúns*. The town of Náhan, the capital of Sirmur, stands on this inner zone, and it is convenient to designate it by this name; it consists of moderately hard thick sandstones and red clays. On the inner side the Náhan group is in abutting contact with the slates, along what may be conveniently referred to as the "main boundary," being that at which a total and permanent change of rocks takes place throughout the whole outer Himalayan border; only in the Simla area do the Náhan beds come into juxtaposition with the Sirmurs at this boundary, and the discussion of their relative ages is a very close one.

The Náhan-Siwálik boundary.

For both the Náhan boundaries the doubt lies in the difficulty indicated in a previous paragraph regarding the interpretation of steep abutting junctions, whether or how far they are original or induced by faulting. It was for a time thought that a certain section of the Náhan-Siwálik boundary gave positive proof of its being an original contact by the interlocking of projecting portions of the two formations in a manner incompatible with a faulted junction, and such as would naturally occur if the newer strata had been deposited against an unevenly worn cliff of the older; but the observation was erroneous, and the question is still an open one. If the feature be due to faulting, the "throw" must be of several thousand feet, for the horizons in contact are topmost Siwálik conglomerates and lowest Náhan beds. In such ground this might not be objected to, but there are other facts against the view of simple faulting: the run of the boundary is sharply irregular, and this is scarcely compatible with a fault of such magnitude; but chiefly, the Siwálik conglomerate here is largely made up of boulders of Náhan (or Sirmur) sandstone, which suggests or requires that when the conglomerate was laid down the relative position of the

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Kohat eocene.

the eocene strata flanking the outer Himalayan hills, and these clay rocks sometimes contain sandy layers rendered conglomeratic by the presence of nummulitic limestone pebbles enclosing nummulites, so that the occurrence of an apparently derived detrital rock of this kind cannot always be taken as evidence of later general age than the rock of which it is formed. Bearing this in mind, it seems not unlikely that the conglomeratic or pebbly layers found at the base of the tertiary beds in the neighbourhood of the Sheikh Budin *gund* represent some stage of the eocene period, a surmise that might even be extended to the more heterogeneous detrital accumulations of pre-tertiary rock, fragments of which form the floor of the tertiary series in the northern part of the Kirí Khasor ridge.

General view of the pre-tertiary series.

We may now make one or two general remarks in connection with the Salt Range or extra-Himalayan pre-tertiary series. The wide range of these deposits through so much of geological time intensifies the peculiarity that strongly-marked discordances, such as are found in other regions, should be absent, the breaks in the succession elsewhere marked by discordance seeming here to have been recorded in the less abrupt form of interrupted succession known as overlap. As to what lengthened periods of duration these overlaps may signify, or how slight may have been the local arrest of deposition, it is impossible to arrive at accurate conclusions; it may even be that some of the isolated deposits are more nearly contemporaneous than there is evidence to prove.

The salt marl and gypsum forming the floor of the series are overlaid by the purple sandstone, to which succeed two other conformable deposits, the *Obolus* and magnesian sandstone groups not known at any place to rest upon the saline group, and therefore to be considered local. These three groups are all overlapped by the sub-carboniferous speckled sandstone, which at one or two isolated and faulted localities in the plateaus of the range, as well as in many of its southern and western sections, next succeeds the gypseous and saline groups. Amid the complications and dislocations near the Indus the speckled sandstone may be itself suppressed, unless faults prevent its appearance between the same saline group and the carboniferous limestone.

The latter group with its accompanying ceratite beds, strongly developed in the west and trans-Indus, dies out in an easterly direction, the triassic portion disappearing first; and the last fossiliferous representative of the carboniferous limestone is situated in the same position below the overlapping cretaceous olive group, as is the red flaggy salt-pseudomorph group of the conformable eastern series. This olive group, dying out westward and but feebly represented trans-Indus, is overlapped by the eocene limestone, which also overlaps the termination of the triassic and jurassic groups, and is itself again overlapped by the newer tertiary detrital beds. These at the east of the range may be found resting on the *Obolus* band and away to the west trans-Indus upon the ceratite group. Thus, although there are but meagre traces of absolute unconformity, there are at least four prominent cases of overlap or suspended deposition.

General view of the pre-tertiary series.

Another point of interest connected with the geology of the region is the reappearance of detritus foreign to the whole of this part of the country in thick boulder clays or thinner conglomeratic beds scattered throughout the series. The crystalline blocks found in the sub-carboniferous deposits of the Khasor range and cis-Indus western Salt Range proper are well rounded far-travelled fragments, often of considerable size, and sometimes polished or even faintly striated as if by glacial action. No similar parent rocks are as yet known amongst the adjacent Himalayan or neighbouring mountains; but the circumstance that these boulder beds occur more or less in the vicinity of the Indus points to the possibility that this ancient river, which transported materials so largely to form the conglomerates of the newer tertiary Siwáliks, may even at the far earlier period indicated have existed and carried down this rounded detritus from unknown regions. Failing this, their source must be sought in lost hills or shores buried beneath the southern plains or connected with the peninsular system of India.

Passing over numerous conglomerate layers in other parts of the series, containing crystalline fragments very similarly constituted, boulder beds recur again in the olive group, as previously mentioned, with distinct evidence of contemporary glaciation, but yielding no more information as to their source. One enormous block of red granite, supposed to have been derived from this group, lies eastward of the Collector's house on the salt-marl of Khewra near the Mayo mines.

SECTION E.—HIMALAYAN DISTRICT—TERTIARIES.

Punjab Himalaya peculiarly interesting;

The Himalayan districts of the Punjab comprise an area of peculiar interest in Himalayan geology. In Kángra, Kulu, and the Simla region there is a very complete display of the great sub-Himalayan system of tertiary rocks, and also the most favourable exposure of the series of limestone slate and schists forming the outer or lower Himalayan mountains south of the great snowy range; while in Spiti the fossiliferous palæozoic and secondary strata on the north of the range are well represented.

due to its terminal position in the range.

These advantages of the position are due to the fact that we have here the beginning of the end of the Himalayan range proper, the snowy mountains of Hindústán. The most striking feature of the case is the complete obliteration here of the broad region, 40—50 miles wide, of lower mountains ranging up to 12,000 feet that everywhere to the east skirts the south of the main range, comprising the district of Kumaun, the kingdom of Nepal, and the territories of Sikkim and Bhutan. The Simla area is the most north-westerly portion of that region. A really well-shaded map would mark this change sufficiently by the corresponding abrupt change of elevation; but on a geological map the feature is most distinct. At the eastern edge of the Punjab, near the Jumna, the sub-Himalayan tertiary zone is only about 10 miles wide, representing thus the condition it maintains eastwards to the far upper end of the Assam valley; but in Kángra this zone is nearly 60 miles wide, due to encroachment on the position of the lower Himalayan region.

Himalayan District—Tertiaries.

older sandstone must have been more or less what it is now. No distinct identification of beds in the Náhans and Siwáliks on opposite sides of the boundary, as implied by faulting, has been made, but it is not denied that such may be possible.

The Náhan-Sirmur boundary.

In the case of the Náhan-Sirmur (main) boundary, faulting to a great extent has probably occurred, yet it is still doubtful whether any part of the Náhan group corresponds with any part of the Sirmur series on opposite sides of the line. On the strength of an admitted general resemblance it has been asserted that the Dagshai and Náhan groups are equivalent, but there are great difficulties in accepting this view. The thickness of strata exposed in various sections of the Náhan zone is greater than the Dagshai group exhibits anywhere in the Sirmur area, yet nowhere have the Subáthú beds been detected outside the main boundary, although they are so freely exposed in the adjoining area inside it. The only possible representative of the Kasauli beds would be the top Náhan sandstone, for clays become more and more abundant low down in the section; yet at the lowest points no signs of the easily-distinguished nummulitic clays have been detected in the many sections that have been explored. The correspondence of the Sirmur and Náhan formations can only be maintained on the supposition that the deposits thickened very rapidly to the south, and that thus the nummulitic beds have been permanently depressed out of sight on the downthrow side of the fault; but until the matter has been more thoroughly investigated it is well to keep the two in view under distinct names. In any case a name would be required to denote the inner zone of middle or lower tertiary rocks, so well defined structurally and so persistent throughout the sub-Himalayan region from the Simla area eastwards, and as typically displayed in the Náhan section.

Difficulty as to fossils.

It may have been remarked with surprise that in this tentative discussion upon the classification of the sub-Himalayan tertiary rocks so little mention has been made of fossils, which are generally understood to be the certain indicators of stratigraphical horizons. The truth of this rule in a very important degree has been already exhibited in the initial determination on no other grounds of two horizons in this great series of deposits, the lower tertiary marine nummulitic beds at the base and the upper tertiary mammalian land fauna at top. But for detailed classification this important branch of geological evidence is in a great degree dependent, and in a new region must always remain so, upon the stratigraphical observations by which the palæontological rule was first established. When once the original order of sequence of the strata has been clearly made out in any one section of a new field, however large, and the distribution of organic remains in that sequence made known, a single fossil from a distant outcrop will often decide with great precision the position of that outcrop in the local series; but the preliminary stratigraphical diagnosis cannot be dispensed with. In many geological regions this is comparatively plain sailing: we have however already seen something of the difficulties that beset it in a mountain region, especially in those deposits whose growth was contemporary with that of the mountains themselves, whereby

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Difficulty as to fossils.

they were subjected to chronic disturbance producing stratigraphical anomalies that never occur under normal conditions of deposition, such as complete conformity and utter discordance within a small group of strata at a very short distance. In ground of this kind fossils would indeed be of direct and immediate aid, where crucial sections are so rarely exposed, as in such a case of discordance, if the same or very closely allied fossils were to be found in the beds thus discordant, the anomalous physical relation would be at once betrayed. Similarly, on a large scale, the detection of the same fossils at distant points in a section would give a safe presumption of corresponding horizons: it is for the due co-ordination of different fossils that a prior stratigraphical study is needed.

Lost vertebrate fossils of Subáthú and Náhan.

Owing to difficulties and mishaps our knowledge is still very unsatisfactory regarding the distribution of fossils in the sub-Himalayan rocks. The great mass of them contain only terrestrial and freshwater fossils, and these are by nature peculiarly capricious in their occurrence. Major Vicary mentions having found bones in the clay on which the Quarter-guard at Subáthú stands, but they were never described and have been lost sight of. That was more than thirty years ago; and it is grievous to think how many thousands of British soldiers have since then spent the season at Subáthú, sadly in want of something to do, and to some of whom at least the search for fossils would have been a pleasant pastime, yet nothing of the kind has been thought of. A similar misfortune happened to some teeth and other mammalian remains found by Colonel Cautley at Náhan, which he identified conjecturally with those he had found in a similar clay at the base of the Siwálik hills east of the Jumna at the mouth of the Kálawála pass. This was just the sort of observation that is so much needed as affording an identification of horizons on opposite sides of the disputed boundary. On account of this, and as several experienced observers had subsequently searched in vain for fossils about Náhan, special reference was made to Sir Proby Cautley on the subject, and he very positively confirmed his statement that he had found the fossils "on the north side of the town of Náhan." All Colonel Cautley's magnificent collections were sent to the British Museum. Dr. Falconer's description of them in the "Fauna Antiqua Sivalensis" was protracted over many years and never completed. In this work the large showy specimens from the outer and newer rocks claimed first attention, so that the smaller things, often of greater interest to the geologist, dropped out of sight, and cannot now be found. Other instances might be given of invaluable specimens being lost for any real use through the mistaken zeal of private collectors, hoarding as curiosities what might in proper hands be important contributions to knowledge. Whatever excuse there may have been in past years for this wasteful practice, there can be none now that a properly-appointed Museum is established in India.

Original confusion of horizons.

All the materials of the "Fauna Antiqua Sivalensis" were obtained in the Punjab, in the outer hills between the Jumna and the Sutlej; for it does not appear that any fossils of the considerable but very local find at the Kálawála pass were ever specifically

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Leading structural features of the western area.

From this nexus of contorted strata originate the flexures which produce some principal features of the sub-Himalayan region to the west. The first great flexure passes down the valley of the Gambhar, and before reaching the Sutlej exhibits what may be called the normal structural feature of the sub-Himalayan region, a junction along which the newer strata appear to dip under the older. A second similar feature, a little to the south, originates in the Mangarh ridge on the left branch of the Sutlej. They both are evidently faulted flexures of apparently great "throw"; and thus bringing rocks of very different horizons in contact, they are geological boundary lines like those already described. In an important respect there is a marked difference between these otherwise similar boundaries: those described to the east exhibit frequent sharp changes of direction, whereas these two in the western area can be traced in remarkably straight lines or very flat curves across the Kángra district and through the Jammu hills into the Jhelum district; they are constantly connected with more or less steep ridges formed of the harder lower rocks on the up-throw side of the fault, always more or less steeply inclined. Away from the line of disturbance newer strata, generally conglomeratic, come in, and the dip flattens to the horizontal, forming *dúns* in the manner already described. There are three principal *dúns* thus formed in the Kángra district. It is here again noteworthy that, although the leading structural features of the sub-Himalayan zone are of the same type throughout, there is complete break of continuity between the actual lines along the lower Himalayan border and to the west of it, although in each area those lines are remarkably continuous.

The Sirmur zone between the Sutlej and Ravi.

It has been said that west of the Sutlej the Sirmur series which in the Simla area is found on the south-western margin of the lower Himalayan region, comes down to form an inner zone of the sub-Himalayan region; and that henceforth to the west the "main boundary" is the inner boundary of the Sirmur zone. The depression, or even partial suppression, of this zone in the Kángra district, and especially in the neighbourhood of the Beas, is an interesting and still obscure point in early Himalayan history. This great torrent leaves the mountains close to the innermost angle where the termination of the lower Himalayan boundary bends into the strike of the main axis along the base of the Dháola Dhár ridge. The gradual introduction of higher beds along the outer boundary of the Sirmur zone (the old "main boundary") north of the Sutlej, and the final overlap of much newer conglomerates across the prolongation of that boundary, have already been noticed. A similar change takes place along the inner boundary (the new main boundary) and throughout the whole zone, which is here some twelve miles wide. The basal nummulitic group entirely disappears, and has not been again detected east of the Ravi; and in the section of the Beas the prevailing type of rock is more that of the Siwáliks than of the lower tertiaries. Near Sih, north of the salt mines at Drang, the topmost beds next the boundary are fresh-looking conglomerates, dipping as usual towards and apparently

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The Sirmur zone between the Sutlej and Ravi.

under the old rocks. This is the most easterly appearance of a conglomerate in the Sirmur zone, and it shows at least that the change noticed here is not merely owing to a local defect of induration. A remarkable fact has been noticed regarding this conglomerate: the top beds contain much large angular *debris* of limestone and pink sandstone found in the adjoining ridge of old rocks; but the rock now most prominent in that ridge, and the *debris* of which is most abundant in the actual talus, is not represented in the conglomerate. It is a trappean rock; and the obvious suggestion is that its intrusion is of later date than the conglomerate, which is what we should expect if this rock is of Sirmur age. Passing on westwards a reverse change sets in, the rocks again presenting an older facies with greater induration and a corresponding increase in the general elevation of the ridges, which is a marked feature throughout the Sirmur zone. The sanitarium of Dharmsála is in this zone, close under the lofty Dháola Dhár at about its middle. South of Palampur a spur of the Sirmur rocks runs south-eastwards and looks like a reappearance of the old main boundary from beneath the overlapping newer tertiaries. Towards the Ravi the Sirmur band becomes very narrow, locally almost obliterated: a condition evidently connected with the extreme disturbance and compression to which it has been subjected in this position. At the end of the Dháola Dhár, west of Dalhousie, the rocks are so crushed up with the slates that the boundary becomes very obscure, and the rocks scarcely identifiable. Fortunately in this very place some plant fossils were found identical with those in the Kasauli beds. It seems impossible not to connect the condition of these rocks here with the extrusion of the gneissose granite of Dalhousie.

The question to be solved.

The question to be worked out in the Kángra district and throughout the region to the west is, how far these successive sections of similar rocks are repititions of the same series. From each of the fault boundaries that traverse the area from end to end we find an ascending series from deep red clays and strongly indurated dark sandstones through gradually paler and softer strata ending in coarse conglomerates. If we could take these boundaries as simple faults, of later date than the newer beds at the contact, and all more or less synchronous, the equivalence of the several bands of similar rocks might be assumed; but the probability is rather that these dislocations were not synchronous, that each took ages to produce, and that deposition was going on all the time. Nothing short of extensive dissection of the ground would make it possible to unravel the stratigraphical complications resulting from such conditions; so the solution must in a great measure rest upon fossil evidence, and this is very scanty. In the two outer ranges some fossils have been found, but not one as yet has been recorded from the inner half of the tertiary area in the Kángra district. As this is the very ground that has been so much taken up by English settlers, we would impress upon them the very great interest that attaches to any find they may make of organic remains, and the importance of noting the position in which they occur.

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The tertiary zone in Jammu.

The town of Jammu stands on the outermost fringe of the Siwálik hills, and the condition of the upper tertiaries in this area is only a continuation of that in Kángra. If however we may take the Jammu hills to mean the tertiary rocks outside the Pír Panjál range between the Ravi and the Jhelum, something has to be said regarding the Sirmur zone. It repeats in a partially reversed way the conditions described in the Simla area. There the lower tertiary series occurred as an outlier among the older rocks, while in Jammu the older rocks occur extensively as inliers in the Sirmur zone. At the Ravi the zone is only a few yards wide, but it expands steadily westwards with increased elevation of the rocks. At the Pine river, 16 miles from the Ravi, the Subáthú nummulitics appear along the outer boundary. At the Táwa, 50 miles from the Ravi, the band is 18 miles wide. Not far to the west, on the Chenab, there are two extensive inliers of massive limestone: the largest occurs at the outer boundary, forming a lofty ridge some 30 miles long, through the very centre of which the Chenab flows by an impassable gorge just above the town of Riassi. This limestone is more massive than that of the Simla area. No fossils have been found in it, and it is only conjecturally correlated with the Krol limestone. These inliers are not, however, like those of the Krol limestone, masses isolated by denudation around which the nummulitic deposits had been laid down; they are altogether the result of later upheaval, for the nummulitics are found on the highest summits of the limestone, and everywhere, as in the Simla area, the bedding in the two formations is conformable notwithstanding their prodigious difference in age. It would thus seem that the pre-tertiary elevation and denudation so well marked in the Simla area had been less effective here. Some important modifications are noticeable in the Subáthú group, the beginning of the conditions that prevail in the extra-Himalayan region to the west. The same pisolitic ferruginous bottom bed occurs here too; but there is a greater concentration of the limestone near the base, and below it we find a carbonaceous band that is not represented in the Simla area, but is the same that has so often raised and disappointed hopes in the Salt Range, the Chitapahár hills near Attock, and all down the flanks of the Sulemáns into Sind. This "coal" is nowhere more developed than on the western flanks of the Riassi inlier; and it is again well seen about the similar inliers on the Púnch river, as at Dandli. As we found the lowest beds of the zone along the outer boundary, so the highest are found at the inner (main) boundary. On the upper Táwi, west of the Bindí gap, strong conglomerates are found nearly vertical next the old rocks, and the puzzle is that they are largely made up of coarse subangular *debris* of tertiary sandstone. This is an opposite difficulty to that noticed in the homologous position at Sih. Again, on a branch of the Táwi, north of Chineni, there is a considerable thickness of pale soft clays, more like Siwáliks than Sirmurs; a search in them for fossils might reveal something.

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SECTION F.—HIMALAYAN DISTRICT—THE MOUNTAIN REGIONS.

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Incomplete as has been the study of the sub-Himalayan tertiary zone, the examination of the higher mountains is still less advanced, and only general indications of the structure can be given. Although the actual features do present three distinct regions, geological as well as orographical, namely, the lower Himalayan, the axial, and the trans-Himalayan or Tibetan regions, in a brief sketch like the present they must be treated connectedly.

Two main rock series.

Provisionally we may speak of two main series of rocks in the lower Himalaya—one of little altered rocks, and the other of mica-schists and gneiss. In the Simla area the former occupy a large portion of the lower Himalayan region on its outer side, while the metamorphics belong rather to the axial region. As we go eastwards the metamorphism increases more and more, so that on the Nepal and Sikkim border there is scarcely a remnant left of unaltered rocks. It is thus evident that the Simla area offers special advantages for observation.

The lower Himalayan series.

The least disturbed section of the lower Himalayan series is that on the main road to and beyond Simla. Immediately inside the tertiary rocks of the Sirmur outlier the road winds round two mountains of limestone, the Boj and the Krol. This limestone is certainly the newest (highest, youngest) of the old rock series on this section, and as yet no newer rock has been finally identified in this area, although the occurrence of such is by no means improbable, seeing the immense break in time between this limestone and the oldest tertiaries. By comparison with the sections in Spiti the Krol rock has been provisionally identified as triassic by Dr. Stoliczka and others who have seen both sections. The Krol limestone is quite unaltered, often earthy and with alternating shales, and at its base there is a variable band of sandstone. Below this group, to the lowest depths of the valleys, we find only shaly flaggy slates, with one important exception : at about 1,000 feet below the Krol sandstone there occurs a small but very well defined group, of wide distribution ; it consists of a clear pale gray, pink, or buff, dense magnesian limestone, overlying a quartzite sandstone which is very generally conglomeratic. The two together do not generally exceed 100 feet in thickness ; they are well exposed in several outcrops along the Blaini stream, which takes its rise west of the Solan rest-house, and hence the group has received the name Blaini. The beds between the Krol and the Blaini groups, classed as the infra-Krol shales, are often carbonaceous, so much so that coal-mining has been attempted in them ; but they are not otherwise very different from the beds below the Blaini group, generally referred to as the "Simla slates," which are often sufficiently indurated and fissile to be used for roofing, as at Simla, but are not true cleavage-slates. The provisional scale of groups is then as follows :—

Krol :—Limestone with shale ;
Sandstone.

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Infra-Krol :—Shales and flags, often carbonaceous.
Blaini :—Clear pale limestone ;
Conglomeratic quartzite.
Simla slates :—Flags and shaly slates.

Want of fossils.

The want of fossils in the lower Himalayan rocks is one of the most disappointing and puzzling features in the geology of the region. All the rocks just mentioned are such as commonly abound in fossils, yet numerous expert geologists have searched these rocks in vain, with one obscure exception ; globular and other concretionary shapes in the limestone have frequently been mistaken for fossils, but one small find of undoubted organic remains was made in a band of limestone low down in the gorge of the Bheng (or Tál), a stream east of the Ganges in the eastern Dún ; they were casts of bivalve shells, but too imperfect for identification. The contrast in this respect with what are supposed to be equivalent rocks on the north of the granitic axis is remarkable, and on that supposition almost precludes the possibility of the basins of deposition having been originally continuous. A connection has thus been suggested between the lower Himalayan series and the great Vindhyan series of lifeless rocks of peninsular India, although there is little or no lithological resemblance between the two : from this point of view it is said that the crystalline rocks of the Himalayan axis may have then formed the north limit of the Indian continental region, and the lower Himalayan area a land-locked basin, and so, for some occult reason, without living beings. Another explanation lies in the correlation of these beds with much older slaty strata of the Tibetan region, which are there also comparatively barren in organic remains. This is superficially the simplest view ; but any decision in the matter would be premature from present knowledge.

Distribution of the Krol rocks.

Where such intense disturbance has taken place the distribution of the rocks is necessarily very intricate. The limestone on the Krol is isolated as a capping ; but from Kanog hill on the east it stretches in a more or less continuous ridge to the Tons, and on both sides of this valley it is found a long way northwards. West of the Krol there is an interruption in the usual fringing ridge of limestone. On the old road to Simla passing under Subáthú it does not appear, but it comes in again at Arki and continues thence northwestwards with very local interruptions, even in the narrow zone between the gneiss and the tertiaries along the flank of the Dhuladhár. For reasons explained in a former section it is natural that this highest rock of the series should occur most constantly in the position of least elevation on the margin of the region ; and we may in an analogous way explain its frequent appearance in transverse areas of depression, coinciding with the great river basins. Thus it stretches far up the valleys of the Beas and the Sutlej which are separated by the lofty Jalori ridge of gneissic rocks. In these positions it often occurs at the lowest levels and reaches up to the summits of the adjoining ridges. The Shali mountain which forms such a picturesque object in the view to the north-east from Simla is a peak of this limestone, rising precipitously from the bed of the Sutlej.

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Section at Simla.

The centre of the Simla area, between the basins of the Sutlej and Tons, is principally formed of the Simla slates; and at Simla itself there is a remnant of the Krol group. The ridge is formed of the northern arm of a local synclinal, and there are several typical exposures of the Blaini group along the northern and eastern sides, at the lower limits of the station. The overlying beds are those of the infra-Krol group, the carbonaceous character being well exhibited at many points on the north side of Jako; the Boileauganj quartzites represent the Krol sandstone; and at Jatogh there is a remnant of the limestone. On the southern side of the synclinal the quartzites form the Tára Devi mountain. The culminating point of this area, and the most conspicuous feature in all this part of the region, is the Chor mountain to the south-east of Simla, rising to an elevation of 11,982 feet. It is of crystalline rock, but is an inlier (surrounded by the Simla slates), and not, like the Jalori ridge, a spur from the axial range. The nature of this rock will be discussed presently.

Trap rocks.

The distribution of the basic igneous rocks in this region is very noteworthy, in their almost exclusive preponderance in the areas of relative depression already noticed. In the section through Simla only one small vein of trap has been detected, near Narkanda; whereas in the adjoining valley of the Sutlej and again in that of the Beas strong irruptive dykes are frequent. It is pretty certain that these intrusions were of middle or late tertiary age. A suggestion to this effect was noticed in the absence of trappean *debris* in the Sirmur conglomerate at Sih, although trap is now conspicuous among the rocks from which the materials of that conglomerate must have been derived. Conclusive evidence has however been reported in the very local intrusion of this trap into the middle tertiary sandstone along the main boundary at the Giri. That such intrusions in the older tertiary rocks should be so exceedingly rare seems, under the circumstances, rather unaccountable; the massiveness and comparative softness of these rocks and their consequent indisposition to fissuring may explain the fact.

Relation of the slate and gneissic series doubtful.

The relation of the lower Himalayan series to the gneissic series is a crucial question in Himalayan history, and one upon which the evidence is still very obscure, or even conflicting. We have, for instance, already entertained two suggestions that are seemingly incompatible in this respect. The notion that during the Krol period there was already a gneissic barrier in the position of the present axis has been put forward to account for the non-appearance of fossils to the south; and some direct local observations seem to confirm this view. In some sections north-east of Simla the Krol group has been described as overlapping the Simla slates and resting upon the flanks of the gneissic range as if in original junction, the actual contact features being only obliterated by subsequent metamorphism. Elsewhere, on the contrary, and at no great distance, as in the Sutlej valley along the south base of the Jalori ridge, the whole Krol group seems to plunge steeply beneath the gneiss. On the other hand, we have seen that the bottom tertiaries were deposited on the uncontorted slates; and it is difficult not to connect that contortion with

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the formation of the principal stratigraphical feature of the mountains the axis to which all these flexures are related. It is true that as a pre-existing ridge its influence under general pressure in determining the direction of secondary axes would have been very similar—we have already attributed the directions of the extra peninsular mountain systems to the form of the older continental mass—and along the fringe of the lower Himalayan region, at a distance from the axial rocks, where we have already shown the great flexures of the later tertiary deposits to have been produced since the adjoining mountains had assumed their present shape, it seems most reasonable to extend a like relation to the slate rocks and the axials. It is where the extreme terms of the series occur in close proximity that the question comes to a crisis: standing on the contorted eocene rocks at the base of the Dháola Dhár, within rifle range of the gneiss forming that precipitous ridge, it seems impossible to imagine that this can have presented anything like its present condition when the eocene rocks were laid down; and the Dháola Dhár, as we have seen, is an exact representative and an actual prolongation of the main Himalayan axis.

What is the axis of the Himalayas?

In description of mountains the word "axis" is of frequent recurrence, and as it may be used in different senses it is well to be able to distinguish these. For the geographer, who deals only with superficial features, the definition would seem simple enough—the chain of loftiest summits determining the axis of the range. In a simple range this presents no difficulty; but in a great complex mountain system, such as we have here to deal with, some safer guide than mere elevation and position is needed, and geology offers the best standard of reference, there being a very close connexion between superficial features and the rock structure. For instance, very lately an official geographer in England has contended that some of the trans-Indus peaks are properly referable to the Himalayan chain. Now this chain, as above defined, coincides with a great stratigraphical axis; a line of granitic intrusion and of maximum upheaval, along which the oldest rocks attain their greatest elevation. As thus most clearly defined, the Himalayan range and axis completely die out within the Kashmir border, and the trans-Indus peaks aforesaid are geologically connected with the great gneissic range of Baltistan. If in geographical portraiture predominance be given to hydrographical basins and their watersheds, the range or axis would be defined by the line of highest gaps instead of highest summits; and under this definition the principal Himalayan axis would be locally placed some 20 miles north of that just indicated, quite away from the geological axis, on a secondary range produced entirely by denudation from the variously yielding outcrops of the sedimentary series on the flank of the gneissic or granitic axis. But some of the principal rivers (as the Sutlej) pass through this range also and drain large areas to the north of it, so it is plain that any regular correspondence between mountain chains and watersheds is out of the question. We have however in the great snowy range, to which the name Himalaya particularly belongs, an excellent example of a mountain chain coinciding with a geological axis.

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The interpretation of watersheds.

Although we have discarded watersheds as forming any criterion in the delineation of mountain ranges and axes, most interesting questions are suggested and sometimes solved by the study of drainage lines. The apparent anomalies presented are often very striking. It is quite common to see a river pass from low ground through a precipitous gorge in a ridge or spur of hard rocks where at a short distance on either side a channel might be formed over flat ground but little higher than its bed, as would inevitably take place if the gorge were dammed ; or we may find a river rising in comparatively low hills, and flowing right through a higher independent range. The easy assumption by which such features have been explained is that there was a natural fissure in the ridge or range. In some instances this may hold good, but certainly not in most cases ; and the true explanation is really more simple. The second of the instances above mentioned, though the larger and apparently more anomalous, admits of the more easily apprehended explanation ; it is, that the river was on the ground before the elevation of the range, and that this process was so gradual that the river could erode its channel *pari passu* with the rise of the ground, as we have seen must have happened during the rise of the outer Siwálik ranges. In the first and more common case, where there is no evidence for the interference of ground movements, the action has to be reversed ; but the reasoning is no less rigorous, for we are working with the absolute fact that water cannot flow uphill. We must in such cases conclude that when the gorge was eroded the ground on the upstream side of the present ridge must have continuously been higher than the water level in the gorge ; that in fact the ridge did not then exist, but has been carved out *pari passu* with the erosion of the gorge, by the general disintegration and denudation of rocks more liable to decomposition than those forming the ridge. This relatively greater or smaller liability of different rocks to denudation by attrition or solution, and the various ways in which such rocks are exposed by the disturbance they have undergone, are the principal inducing influences in the formation of all the varied features of mountain sculpturing. Before scrutinizing the Himaláyan features from this point of view, a few words are needed as to what would take place normally (*i.e.*, without the interference of disturbance) under such conditions. Suppose an elevation to take place, longer than broad, and with a more or less central axis or crest of maximum elevation (to both of which conditions there would be a natural tendency) : drainage would then take place from that crest by the most direct fall. The original cast of the principal valleys would thus be almost wholly transverse to the axis, and would remain so for ever if the elevated mass were homogeneous. As this never occurs, a tendency sets in by which any river that has happened to erode more deeply than the others gradually draws off the drainage of its neighbours ; and so the main drainage, from being originally all transverse, becomes to a great extent longitudinal, *i.e.*, parallel to the axis. The process is very simple : the elevated mass is sure to be mostly made of stratified rocks of different composition and hardness ; these become tilted up in lines more or less parallel to the axis of elevation ; and as a

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matter of course the lateral drainage of the original transverse valleys begins to operate along the softer beds, leaving the harder ones sticking up as spurs; and thus at first any pair of lateral streams will start a watershed about half way between two main transverse valleys. If in either of these latter the cutting down of the channel proceeds more rapidly than in the other, the same must take place in its lateral stream, the watershed of which will thus be cut back until at last it will reach the adjoining transverse channel, and carry off its waters down the steeper course. In this way a whole chain of secondary streams may be connected into one principal longitudinal river, to which the head waters of the original primary transverse streams become affluents; and with each such accession the eroding power is increased and the process thereby extended. That such a process has operated is a well established fact; the lower gorges of the original transverse streams thus cut off remain as gaps in the ridge on the outside of the new longitudinal valley. There would of course be a corresponding tendency on the side of the more rapid drainage to cut back the primary watershed, but the chief factor in the process just described is the immensely greater facility of erosion along the strike of softer rocks; upon any harder rock in the original axis such erosion would be incredibly slow: and hence the corollary we have been seeking for—that within certain simple assumptions the initial axis of elevation would tend to be perpetuated as a main watershed.

An imaginary Himalayan axis.

Although we can by no means apply the simple assumptions aforesaid to the immense area of elevation of which the Himalayan chain forms a part, there may be some use in seeing what hints the drainage test may give. The main watershed between north and south is in the Mustag and Karakoram range, whence flow the northern affluents of the Indus, far to the north of what we must for the present call the Himalayan axis. This is of course a fact to be explained; but it is beyond our present scope, for it is certain that within this great area there were several axes of relative elevation and depression, whether synchronous or successive, and we are only concerned with the most southerly one. Of this we have already seen that the actual Himalayan chain coincides with a geological axis of maximum upheaval and of granitic intrusion, but it is quite possible that this may not be the axis we are in search of—the line of maximum effect due to the disturbance by which the contortion and elevation of the tertiary rocks was accomplished, which is perhaps what would be generally implied by "the Himalayan axis" from the geological point of view, for the Himalayan elevation is accepted as of tertiary date. The drainage test directly suggests such an idea, *viz.*, that the spill of the waters originated in a crest of greater elevation to the north of the actual mountain axis; and it is easy to indicate how such a crest may have been formed there, supposing the gneissic axis to have been in its place from very ancient times. A broad area to the north of this axis is occupied by an immense series of stratified rocks, ranging from unfossiliferous slates through palæozoic and secondary formations up to the cretaceous system. Now we know that the chief results

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An imaginary Himalayan axis.

of crust movements are proximately due to tangential pressures, which naturally take effect upon the most compressible materials, such as would be a mass of comparatively unconsolidated strata of variable composition. Under such a process the yielding mass would be squeezed downwards as well as upwards, so that the same axis might be stratigraphically one of both elevation and depression; and in fact we do commonly speak of this ground as a "basin," the newer rocks lying in a trough between two great protrusions of gneiss. It is in no way extravagant to suppose that a crest of maximum elevation may have been thus formed in tertiary times over this ground, from which originated the drainage crossing the older gneissic axis. Volcanic action may be largely called into play in support of this view, for there is a prodigious display of basic eruptive rocks connected with the newer sedimentary formations in Ladák and Hundes, where there may once have been a line of volcanic cones like those of the Andes. The subsequent greater erosion of that area would be due to the same cause as its elevation, the comparative softness of the rocks. If on the other hand the gneissic axis should prove to be of tertiary date, it would imply that the sedimentary series then reached across it, and that the Himalayan elevation was incomparably greatest on that line, where even now the oldest schists overlook the newer sedimentaries to the north. The watershed anomaly would then have to be explained as the natural result of the much greater steepness of the fall to the south, and also of the immensely greater rainfall on this side.

The granite.

We may now see what the gneissic axis has to say for itself. "Granitic axis" might be a more distinctive name for it, as there are in this region other gneissic axis that do not possess this character, the geological importance of which is immense although of uncertain interpretation. The rock was described as albite granite by Dr. Stoliczka (Memoirs, G. S., I., Vol. V), who was the first professional geologist to publish his observations on this ground; but Mr. Mallet has since shown that the felspar is oligoclase, not albite, by the analysis of specimens from the same locality, Wangtu bridge on the Sutlej. In the middle Himalaya, north of Kumaun, this rock takes a prominent part in the formation of the highest peaks; on the Sutlej it is also in great force, and it is still represented in the divided prolongations of the range by the gneiss of Zanskár and of the Dháola Dhár. This granite is undoubtedly the youngest rock in this axial range, and the function it performed (if any) in "the Himalayan elevation" is a very crucial question; Captain R. Strachey gave expression to a still prevailing opinion bearing on this point when he wrote (Quar. Jour., Geol. Soc., London, Vol. VII, 1851)—"The fact of the granite of the great snowy peaks being seen in veins, penetrating the schists up to 20,000 feet [on a previous page he mentions it as forming peaks 25,500 feet high], makes it highly probable that the granite must have been injected long before the mountains received any considerable development." Still this would not preclude its immediate connection with "the Himalayan elevation"; to ascertain this we have to determine the age of the granitic intrusion. The

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The granite.

only positive information we possess would place this event in a very remote age. Dr. Stoliczka quotes (*l. c.* p. 12) verbal information from General Strachey that the granite penetrates silurian and even secondary strata; but there may be some mistake here, for in the paper already quoted it is only described as penetrating the schists, and the opinion is clearly recorded—"That this granite is older than the silurian period is rendered probable by the comparatively unaltered state of the lower beds of the azoic slates at the foot of the palæozoic series, where almost in contact with it;" and General Strachey had not again visited the ground. He moreover gives it as his opinion that the gneissic range formed a barrier, though of course not with its present elevation, in palæozoic times. A confirmatory observation is recorded by Col. McMahon in the Spiti valley near Chango, where granite veins pervade the mica schists, but stop short at the contact of the overlying palæozoic slates and limestones. Still, these facts are not final; we have already seen how very rarely the eruptive traps of the lower Himalaya penetrate the tertiary rocks, although certainly of later date.

The gneissic rocks.

The crystalline stratified rocks forming the chief mass of the axial range are often spoken of as the gneissic series from their most conspicuous member, but on the whole there is perhaps a preponderance of non-felspathic quartz and mica-schists with some few hornblendic beds. These alternate with thinly bedded gneiss; but amongst them, and apparently interstratified, there is a very massive porphyritic granitoid gneiss to which special interest attaches. Dr. Stoliczka described this whole crystalline series under the title of "Central gneiss," considering it to be the principal geological axis of the Himalaya, and from an assumed homology with "the central gneiss of the Alps"—a comparison that is hardly borne out by structural evidence—but the name has more especially clung to the massive gneiss. It is from the stratified rocks that structural features can be made out, and from this point of view the gneissic axis does not present the symmetry that would be naturally associated with the word "central," and such as is often presented by axes of crystalline rocks, to or from which the rocks on either side have a prevailing dip. The strata of the gneissic axis offer no exception to the rule that prevails throughout the lower Himalaya as well as in the tertiary zone, that of a greatly prevailing northerly or inward dip. On its northern flanks these rocks are overlaid with rough conformity by the lowest slates at the southern outcrop of the sedimentary basin, while on the outer flanks we have seen the lower Himalayan rocks abutting against it in a very confused manner. Dips of course involve flexuring of the strata; and that any one dip should prevail over a large area requires that the flexures should be much steeper on one side than on the other, whereby the strata on that side would occupy less area, or even be broken and faulted out of sight. This absence of symmetry would imply a one-sidedness of conditions, contrary to what might be expected in a "central axis." It is of course possible that there might be no such central feature in a mountain system; but if one

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The gneissic rocks.

should occur it would seem to claim attention as probably of dominant significance in the development of the mountains. Now such a line is found in the "imaginary axis" mentioned in a former paragraph. The series of palæozoic and secondary strata to the north of this gneissic axis form a broad synclinal trough, on the north side of which in Rupshu crystalline schists and gneiss appear again in great force but with a steady southerly dip. Along this inner gneissic axis of Ladák we find moreover the significant fact that the palæozoic rocks have themselves undergone considerable metamorphism. These comparative considerations tend again to suggest that the Himalayan gneissic axis is of pre-Himalayan origin.

Granitoid gneiss or gneissose granite.

Very lately (1883) a new and most important interest has been conferred upon the massive granitoid gneiss that is so conspicuous amongst the rocks forming or adjoining the Himalayan axis. It appears that we must henceforth speak of it as "gneissose granite." No doubt the fact indicated by the change would be equally expressed by the term eruptive gneiss; and if the classification and nomenclature of rocks were to be altogether artificial and based upon researches in the cabinet, whereby foliation would be the one distinguishing character between gneiss and granite, the former name would have to be retained for this rock. If lithology had any *raison d'être* as an independent science such a method might be justified: but in reality lithology is quite a barren study unless as ancillary to geology, just as zoology is to biology. The natural classification of rocks can as little afford to ignore their functional characters as the natural classification of living things could dispense with physiological considerations and depend solely upon morphological characters. Now in geology the paramount signification of granite is that of eruption in a more or less plastic fused condition; and no less does the word gneiss imply that the form and association of the rocks are due to original deposition, whatever change of texture it may have undergone by molecular action, the foliation being due to original lamination or to cleavage. As an exceedingly general rule foliation is known to be a character of metamorphosed sedimentary rocks, and as a no less general rule the texture of granite is amorphous. It has however been observed that a viscous igneous rock under eruption may acquire by traction a streaked texture which would on crystallisation result in foliation, and it was long ago pointed out by Scrope that the gneissose texture might be simulated in this way; on the other hand it is conceivable that by extreme metamorphism a wholly amorphous crystalline texture might be locally produced in a bedded rock, without any disturbance of its normal structural relations. In these very exceptional cases, the true nature of the rock and the name it should receive can only be determined by close study on the ground, the terms "gneissose granite" and "granitoid gneiss" being for each case the natural expression of the result. Independent scientific observers have become so scarce of late in India that it is especially gratifying to be able to quote one of that brotherhood as the author of an important discovery, for so it deserves to be called. Colonel C. A. McMahon,

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Granitoid gneiss or gneissose granite.

formerly Deputy Commissioner of Simla and now Commissioner of Amritsar (which gives him the run of the Dháola Dhár), has been the first to bring the microscope to the study of Indian rocks; and it has led him to what is very nearly a demonstration that the granitoid gneiss of the Himalayan axis is truly an eruptive rock. Perhaps the best evidence in favour of this judgment is that it gave immediate relief to almost insurmountable stratigraphical difficulties. Where this rock appears amidst the gneissic schists of the great range there is little to suggest its being other than what it seems to be; continuous observation being very difficult in that region, only passing notes have been made along widely-separated sections. It is when this identical rock appears in more accessible ground, and in juxtaposition with little altered rocks, that as gneiss it has presented such difficulties of interpretation. The Chor mountain which has been mentioned as forming the most conspicuous feature in the Simla area is a typical case. The whole summit for several hundred feet is of this massive porphyritic granitoid rock, of exactly the same type as that in the main range; it is not only that it is characterised by the more or less distinct foliation and massive bedding, but its behaviour (*allure*) is very much that of a normally intercalated mass: it presents the usual steep southerly outcrop, while to the north it is overlaid at a moderate dip by schistose slates. It has however no continuity in strike, the area it occupies is as broad as it is long, with a diameter of about seven miles, and members of the lower Himalayan series appear close by on either side of it without extensive metamorphism. Still, in the absence of the usual positive signs of igneous intrusion, it was thought safest to accept it as belonging to the old gneiss, although very forced suppositions had to be made to account for its position, whether altogether by faulting, or partly as a mass already isolated when the Krol rocks were laid down.* A similar stratigraphical puzzle presented itself in the Dháola Dhár, where that range ends abruptly at the gorge of the Ravi, the gneissic mass, where it is still six miles wide, being truncated at right angles to its strike. Colonel McMahon has since observed that the granitic rock here is continuous, but reduced to a width of 250 feet along the northern edge of the outcrop, coinciding with an axis of flexure and of eruption, as is now maintained. When first describing the massive gneiss in the Simla region (Records, G. S. I., Vol. X, p. 222, 1877) Colonel McMahon remarked that "the internal structure of the rock is that which has usually been described as characteristic of an igneous rock." Subsequent and more leisurely study of the same rock and of its contact action on the schists in the Dháola Dhár at Dalhousie has led him to the conclusion that this pseudo-gneiss is truly an eruptive (intrusive) rock, and therefore to be called "gneissose granite" (Records, G. S. I., Vol. XVI, p. 143, 1883).

Age of gneissose granite.

A conjecture is further hazarded that "instead of being an archæan, cambrian, or 'converted' silurian rock, it is in reality of

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* See Memoirs, G. S. I., Vol. III, Pt. 2, p. 46. It should not be forgotten that the observations referred to, from which our description is taken, were only cursory, during two traverses to north and south of the mountain.

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Age of gneissose granite.

tertiary age and was brought into its present position in the course of the throes that gave birth to the Himalayas." It has been said before that nowhere is the relation of cause and effect between the Himalayan upheaval and the contortion of the lower tertiary strata so vividly suggested as along the Dháola Dhár, where very marked occurrences of both conditions are found close together; but this same juxtaposition renders it very difficult to accept this supposition in view of the eruptive character of the great mass of crystalline rock forming the ridge. It may be taken as certain that nothing like eruptive action in the full sense of the word took place here during tertiary times, for the full sedimentary series of that era in the immediate neighbourhood is entirely wanting in volcanic material. The character of this intrusion, so free from disrupting effects, would independently show that it must have been a deep-seated operation. We can then at least affirm that, if the eruption of this gneissose granite be of tertiary age, the entire mass now forming the Dháola Dhár, ranging above 16,000 feet in elevation, must then have been deep under ground. It is presumable that the same inference would have in some measure to be applied to the whole Himalayan axis: and the determination of age would apply *à fortiori* to the disruptive oligoclase granite, which must be newer than the gneissoid granite. Still neither this consideration nor those previously mentioned as bearing on this question would absolutely prohibit the suggestion of a tertiary age for this plutonic rocks, or of the existence of a very ancient ridge of archæan rocks in the position of the Himalayan axis. When this axis was spoken of as one of maximum upheaval, on the obvious ground that the oldest rocks are there found higher than the newest, aggregate upheaval was understood, which would not at all necessarily imply that the greatest elevation attained within this region had been on this axis. A gradual uprising along this line, including the whole lower Himalayan region, may have coincided with the slow depression of the sedimentary basin to the north; and the injection of the two granites may well have been delayed until the period of the greater movements which attended the Himalayan elevation proper. The extrusion of highly silicated plutonic rocks would naturally occur amongst the older rocks adjoining the principal focus of disturbance.

Peculiar metamorphism in the Simla region.

Certain abnormal circumstances of metamorphism, for which no satisfactory explanation is known, have frequently attracted notice at Simla. All the upper beds forming the summit and southern face of Jako, round which mountain a great part of the station is built, consist of thorough mica-schists with abundant quartz veining, while the base of the mountain is formed of slaty rocks exhibiting little or no crystalline metamorphism. Now there seems no question that all these rocks are in normal sequence, the altered beds being of the infra-Krol group, resting on the Blaini band and the Simla slates; so that the supposition of inversion is inadmissible. Similar conditions are found on Mahásu, the next ridge to the east-by-north. The feature is noticed here, as a sort of forlorn hope, in connexion with the extensive lateral intrusion of the

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gneissose granite. This rock forms a nearly horizontal capping to the Hatu mountain, with what are taken to be lower Himalayan rocks close upon its flanks; but Hatu is 20 miles from Jako. The stratigraphical conditions required for the accomplishment of such a feat are too appalling to be contemplated; the suggestion is only made here to exhibit how much we have still to learn regarding the geology of the lower Himalayan region.

The trans-Himalayan region.

In crossing the Himalayan range we pass geologically no less than geographically out of India, from an anomalous country in which the standard stratigraphical tokens are almost wholly wanting, and where the geologist has to fall back upon first principles, into a land where he at once feels at home, the rocks being more or less amenable to an established code of evidence. Resting upon the northern flanks of the gneissic range there is a great thickness of slates in which silurian fossils have been detected, and they are overlaid in more or less normal sequence by upper palæozoic and mesozoic formations ending with the cretaceous. The general distribution of these sedimentary rocks presents a broad regularity that is most promising of results to future study. There is a principal division into two great longitudinal basins (in the stratigraphical sense), separated by the gneissic axis of Ladák; the northern basin lies between this axis and the crystalline range of the Kuenlon; the southern basin lies between the Ladák and the Himalayan gneissic axes. Regarding the former we have very little information. The best known section is near the western end in the Karakoram ridge, which seems to be a spur from the crystalline centre of the Mustag in northern Baltistan. The southern trough is partially known in what we may take as its western half, west of the middle Tibetan watershed near the Manasaraur lakes. At this point the sedimentary basin is partly interrupted by the crystalline mass of the Gurla mountain, which seems from General Strachey's map to be connected with the central gneissic range rather than with the Himalayan axis. At about 200 miles to the north-west the trough is again almost intercepted by the granitic or gneissic mass of the Purguil mountain, the intermediate ground forming the plateau of Hundes, and the upper basin of the Sutlej. Here too the palæozoic rocks are continuous along the Himalayan side, south of Purguil, passing on into Spiti, where the whole sedimentary series again expands to form another elipsoidal basin about 200 miles long reaching nearly to Drás. This geological sub-region is best known as the Zanskár basin, as a very large proportion of the area is drained by the river of that name, a southern affluent of the Indus. The best known sections are in the basin of the Spiti river, an affluent of the Sutlej, but it only drains the south-east corner of the region. In the far north-west we find the palæozoic strata continuous across the termination of the attenuated representatives of the Himalayan gneissic axis; first by the Zoji pass into Kashmir, and thence along the Kishnganga valley to the south flanks of the Pír Panjál axis, whence there is a continuous outcrop into the lower Himalayan area. With patience and perseverance we may thus expect to establish a

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circuitous but connected identification of geological horizons between the rock series on opposite sides of the Himalayan axis.

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The Spiti section.

The most complete known section of the trans-Himalayan rocks is that worked out by Dr. Stoliczka in the Zanskár basin, and principally in Spiti, through the abundant evidence of fossils (Memoirs, G. S. I., Vol. V, 1865). The following scale of formations has been there established :—

Mesozoic.

- (*n*) Chikkim Shales (*cretaceous*).—Dark grey marly earthy shales; 200 feet.
- (*m*) Chikkim Limestone (*cretaceous*).—White or grey: when earthy gives a bituminous odour when struck; 600 feet.
- (*l*) Gieumal Sandstone (*upper jurassic*).—Yellowish, silicious; darker and calcareous; sometimes a loose grit and even coarsely conglomeratic; 600 feet; conformable to and interstratified with (*k*).
- (*k*) Spiti Shales (*upper jurassic*).—Black crumbling shale, full of calcareous concretions, each generally containing a fossil; 300 to 500 feet.
- (*i*) Shaly Slates (*jurassic*).—Brown or black, full of broken shells; 50 feet; very local, probably belong to (*k*).
- (*h*) Upper Tagling (*lias*).—Dark, earthy, bituminous; about 1,000 feet; difficult to distinguish from (*g*).
- (*g*) Tagling Limestone (*lower lias or rhætic*).—Dark grey brown or black, sandy or earthy, often oolitic and bituminous, sometimes a shell limestone; more than 1,000 feet; locally unconformable on (*e*).
- (*f*) Para Limestone (*rhætic or upper trias*).—Black, dolomitic, strongly bituminous, often earthy; 700 feet; only found on the north side of the basin.
- (*e*) Lilang Series (*upper or middle trias*).—Dark limestone, calcareous slates and shales; limestone compact or fairly oolitic; 1,000 to 2,000 feet; locally unconformable on (*d*).

Palæozoic.

- (*d*) Kuling Series (*carboniferous*).—Pale quartzites at base alternating with brown shales; the latter are often carbonaceous and calcareous, passing into dark limestone; 100 to 400 feet; junction with (*c*) conformable, obscure.
- (*c*) Muth Series (*upper silurian*).—
    3. White quartzite, often speckled; 200 to 300 feet.
    2. Pale sandy silicious limestone; 300 to 400 feet.
    1. Purple sandstone, slaty partings; conglomeratic, 500 to 600 feet; conformable to (*b*), slightly alternating.
- (*b*) Bhabeh Series (*lower silurian*).—
    3. Greenish and bluish sandstones, sometimes micaceous, often laminated; also thick slaty and calcareous beds; thickness not given, but figured as equal to No. 1.

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The Spiti section.

2. Grey white and pinkish speckled sandstone or quartzite, with occasional calcareous beds dolomitic and cavernous; thickness not given, but figured as equal to No. 1.
1. Bluish and greenish grey slates (some micaceous) and sandstones; 3,000 feet.

(*a*) CENTRAL GNEISS.

The several members of this great series are thicker or thinner, or even locally absent, in different parts of the basin; but no decided discordance has been observed, so that it would appear that no considerable disturbance can have occurred here during the immense lapse of time represented by these deposits. There is only a remnant left of the cretaceous rocks capping a ridge in the middle of the basin. The most obscure point of the section is perhaps the basal junction with the gneissic rocks: it is figured as in a manner discordant, but scarcely such as what might be expected if this gneiss had formed a bounding ridge in the silurian sea.

The tertiary rocks of the Upper Indus Valley.

Although tertiary rocks do not appear within the trans-Himalayan districts of the Punjab, it is necessary to mention them, as their position and their relations to the older rocks of the region form the most striking stratigraphical feature bearing upon the history of the mountains. Throughout the region east of India, in Burma, and extending even to eastern Bengal (the Assam range), the conformable and even transitional relations between the cretaceous and the tertiary deposits are constant. Similar relations obtain in the region west of India, in Bilúchistán, on the Afghán frontier, and even locally in the Salt Range. In the sub-Himalayan and lower Himalayan regions we have seen, on the contrary, that the lowest tertiary beds rest directly, although with general parallelism, upon very old rocks, either lower secondary, or palæozoic. In the central Himalayan region this isolation of the tertiary deposits is even more marked, because there the whole secondary series is very fully represented, yet the distribution of the two series is as distinct as it could be; they do not even touch at any point. The tertiary deposits occupy a long narrow trough, very closely corresponding, except at its western extremity, with the valley of the Indus, which lies obliquely along the gneissic axis of Ladák. The character of the rocks correspond with such a location as one of original deposition, having on the whole a remarkable resemblance to the Sirmur series of the sub-Himalayan region; thick sandstones and clays of the sub-Himalayan type, with some conglomerates. Mr. Drew found marine or estuarine shells at the western end of the basin near Kargil, and Dr. Stoliczka got nummulites further to the east, near Leh. From some sections it has been shown that the contact with the gneiss is original, not due to faulting. These deposits have undergone great disturbance, the extent of which increases to the east; and on the south side of the Indus they form mountains of considerable elevation, as in the Miru peak (19,577 feet), the level of the river here being about 10,600 feet. The trough is seldom more than 25 miles wide, extending for 200 miles from Kargil to the Chinese frontier, and beyond it into central Tibet. Where Dr.

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The tertiary rocks of the Upper Indus Valley.

Stoliczka first observed these rocks in northern Rupshu, they are so indurated and altered that he took them to be a palæozoic formation. It is in and principally along the southern side of the tertiary series that the basic eruptive rocks are so largely exposed. They are already in force close to Kargil, but their greatest development is to the east, where they are no doubt continuous with the similar rocks described by General Strachey about the Manasaraur lakes.

Conclusion regarding the history of the Himalayas.

It is easy to see the leading inference regarding Himalayan history to be drawn from all these facts. It remains true that the rocks now forming the summit of Miru and other higher ground must have been at the sea level at the commencement of the tertiary era; but it is scarcely less clear that a great deal of the work directly connected with the formation of the Himalayas had been accomplished in immediately antecedent time. If we could suppose that the secondary basins of Zanskár and the Karakoram had been continuous, the change between cretaceous and tertiary time would involve the upheaval of the gneissic axis of Ladák as a true centre of elevation, and its conversion by a prodigious denudation into a potential marine basin, through depression. But even supposing that crystalline range to have formed a barrier in the cretaceous seas, a change involving a more or less complete reversal of the distribution of land and water must have occurred before the tertiary deposits could take the place in which we find them. It seems not unlikely that the tertiaries of the upper Indus were once continuous with those of the sub-Himalayan zone; for some remnants of these beds have been observed about Drás, on the watershed lying directly between the present terminations of those regions.

SECTION G.—THE AFGHAN REGION.

The Afghán Region.

The mountains of the North-west Frontier, although confluent with the Himalayan ranges, are distinctly separable from them, on many grounds. The prevailing directions of the two in adjoining areas are more or less at right angles. This feature is most strongly marked in the tertiary rocks along the Jhelum, where throughout a direct distance of more than 100 miles the strike of the beds may be seen to bend even at an acute angle, from north-north-west on the Jamu side to south-south-west in Hazára. The constancy of direction is by no means so marked in the western mountains as in the eastern. This is most plainly seen along the border of the plains, which in each case corresponds with the strike of the ridges and of the strata; the steady run of the sub-Himalayan border contrasts most markedly with the zigzag edge of the hills beyond the Jhelum. And this irregularity is not confined to the border zone of the western area: the principal range is the Hindu Kúsh, with a south-westerly trend, which seems to be continued to the south-west of Kabul in the range between the valleys of the Helmund and the Argandab; but on both sides we find considerable ranges with an east-west direction, as in the Safed Koh running

The Afghan Region.
The Afghán Region.

westwards from Pesháwar, and the Koh-i-baba west of Kabul. Again, the Sulemán range runs north and south, but between it and the similarly placed ranges in Sind there are the Marri and Bhugti hills having an east to west trend. Any attempt at natural sub-divisions of this ground would be premature from existing knowledge, when on the best maps the features of even the principal ranges are to a considerable extent conjectural. Indeed the best maps of our own completely surveyed districts do not adequately exhibit the characters of the hills; but this is a complaint we shall not get rid of until those who undertake the portraiture of such features understand something of the anatomy of the objects they would represent. It will be convenient to speak of all the trans-Jhelum mountains as the Afghán region. The Salt Range, cis and trans-Indus, would in a manner belong to it, but we have seen that in structure and composition this range is unique, a remnant of an ancient fringe of the peninsular region wholly cut off from the extra peninsular mountains by a broad area of tertiary deposits.

The gneiss.

The British districts occupy only the outskirts of this great mountain region, principally in Hazára, between the Jhelum and the Indus; but this is geologically the most interesting portion, as including the unaltered rocks outside the gneissic mass that forms almost exclusively the whole region to the north. The deep re-entering bay of tertiary rocks up the valley of the Jhelum stretches far beyond the bend of this river at Muzaffarabad to near Kághán on the Kunhar river in upper Hazára, and here the lower tertiary deposits are in contact with gneissose schists on the flanks of the gneiss itself. The older fossiliferous rocks of Hazára are thus completely cut off from the corresponding rocks of the Himalayan region, and the structural distinction of the two regions is further marked by the fact that this gneiss of Kághán is not connected with that of the Himalayan range proper, but with that of Baltistan and Ladák. From Stoliczka's observations it would seem that the gneiss of the Kuenlon and of the Pámír belong to the same mass, and it is presumable that the gneiss of the Hindu Kúsh is its western extension. Within this immense area there no doubt occur numerous outliers of less altered rocks, possibly fossiliferous, preserved in synclinal folds of the gneiss, such as have been mapped by Mr. Lydekker in Baltistan (Memoirs, G. S. I., Vol. XXII), or such as Mr. Wynne has indicated in the Agror district of northern Hazára (Records, G. S. I., XII, p. 123), but the gneiss seems to be continuous throughout. Its southern limits stretch across Hazára through Mansahra to above Amb on the Indus. There is constantly a broad fringe of gneissose schists, and here, as in the outer Himalaya, these dip uniformly towards the gneiss as if passing under it, and in the deep river gorges the outcrop runs far up-stream, further suggesting the actual super-position of the gneiss. The Máhaban mountain trans-Indus is formed of the gneiss, which probably continues thence throughout the range north of the Pesháwar valley, and westwards into connexion with the metamorphic rocks of the country about Kabul, and forming the crest of the Safed Koh.

The Afghan Region.

The Sirban section.

The unaltered rocks forming the hills of southern Hazára (some of which are over 9,000 feet high) present most intricate sections, being much more contorted than is usual in the Himalayan region. Fortunately one of the least disturbed sections, that of the Sirban mountain south of Abbottabad, has been carefully described (Memoirs, G. S. I., Vol. IX), giving a clue to the normal relations of the rocks. The following formations occur there:—

6. Nummulitic: Thick limestones with some shales and fossils in places.
5. Cretaceous: Thin bedded limestones, no fossils found.
   Earthy ferruginous sandy limestone, with fossils.
4. Jurassic: Black Spiti shales, with fossils.
   An erosion unconformity occurs here.
3. Triassic: Thin bedded limestone and slaty shales.
   Dolomite limestone, with fossils.
2. Below the trias: Cherty dolomite, quartzite, breccia and hæmatite.
   Unconformity.
1. Attock slates: Subschistose slates with limestone.

The thicknesses are not given, because they vary much in different sections, but the aggregate of the mesozoic groups (2 to 5) here must be within 2,000′, for the height of Sirban is only 6,243′, and the Abbottabad plain has an elevation of 4,000′; in neighbouring sections the nummulitic beds by themselves (chiefly limestone) attain many hundred feet (perhaps thousands) in thickness. All the groups from 2 to 6 are in parallel super-position, but the group (No. 2) below the trias rests transversely on the edges of the Attock slates, a more total unconformity than has anywhere been observed in the Himalayan region, except that of the Indus tertiaries on the Ladák gneiss. Another point of contrast with the Himalayan area is the development of the nummulitic as a great marine formation in continuous sequence with cretaceous beds, instead of as isolated estuarine deposits. In other respects there is some correspondence with the central Himalayan rocks, as in the identity of the jurassic group with that in Zanskár and Spiti.

The older sedimentary rocks.

As usual, it is with the unfossiliferous deposits that the difficulties of classification arise, and in that category we must still count group 2 of the list. The Attock slates, so called from the hills south of Attock, where they are well exposed, have been generally quoted as silurian, on the strength of some fossils of doubtful identity found long ago in blocks of similar stone from the Khyber hills. If this were confirmed group 2 of the list might possibly represent the carboniferous period. But it has been suggested by Dr. Waagan (Records, G. S. I., XV, p. 183) that the Attock slates may be carboniferous, on the evidence of some undoubtedly carboniferous fossils found by him in the collections of the Geological Society of London, labelled "Punjab," and occurring in a black slate for which he could find no representative unless in this formation. Upon this suggestion he points out that group 2 of the list would normally represent the Muschelkalk and Bunter groups of

The older sedimentary rocks.

the triassic system, No. 3 being the Keuper, or upper trias. But a leading feature in the puzzle has reference to some rocks not yet mentioned, and described by Mr. Wynne (*l. c.* p. 122) as the Tanáwal ("Tanol") group from the name of the district in which they occur between Abbottabad and the Indus. They are separated from the Sirban mountain by a band of Attock slates four miles wide, and divide these on the other side from the schistose and gneissic rocks of the higher mountains, with which rocks they are described as being associated, and as appearing to pass both into and underneath them. The figured section (*l. c.* p. 117) would imply either that the gneiss of Bahingra is the newest rock of the sequence, or that there is a prodigious inversion of the whole series. Both suppositions would be so extreme that we may assume the oversight of some fault or flexure which will admit of a more reasonable interpretation. The contact of the Tanáwal rocks with the Attock slates on the south-east is described as either a fault or a complete unconformity, the slates being presumably the older of the two. The Tanáwal group is made up of quartzites, dark shaly slates* and cherty dolomites, having some resemblance to group 2 of the Sirban section, although here the dolomitic limestone is the predominant rock, Mr. Wynne however considers the groups to be one and the same, having traced the Tanáwal beds to the north-east into the Tandiáni mountains, on the strike of the Sirban section. Along the eastern flank of the Tandiáni mountains Mr. Wynne traced the Attock slates into contact with the schists bordering the gneiss in the Kunhar valley east of Muzaffarabad where the two are transitionally associated. This observation goes far to settle the later age of the Tanáwal rocks, and so far to confirm their identity with the infra-trias group of Sirban. Here too the Attock slates are within a short distance of the silurian slates, across the narrow bay of tertiary rocks, as mapped by Mr. Lydekker in the Kashmir territory. There seems very little doubt that the two series are the same.

General distribution.

The section described in Hazára is the fullest known in this region, and no other formations have to be introduced. The general distribution is about parallel to that already indicated as the south limit of the gneissic mass. From an almost southerly direction in the north-east, in the Tandiáni hills (8,845 feet), the strike gradually bends westwards, and before reaching the Indus the east-west range of the Safed Koh is fully established. There is however an almost complete break of continuity in the hills, through a great intervening alluvial basin. The mesozoic rocks of Sirban do not extend beyond that mountain to the south-west, in which direction within a few miles the Attock slates gradually disappear under the gravels of the Haripur plain. The Tanáwal rocks extend for some miles along the left bank of the Indus to the south-west from Torbela, and are connected on the south-east with the schists and Attock slates of the Gandgarh range, round the point of which the Haripur plain is confluent with that of Chach facing the plain of the Kabul river on the opposite side of the Indus. The Attock hills are a

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* These might well have been the source of Dr. Waagan's carboniferous fossils.

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The Afghan Region.

General distribution.

revival on the strike of the Gandgarh range; but they stop out below Cherat, at Julozai, where the slates are again covered by the gravel slopes south of Peshâwar. There can be little doubt that the Attock slates and probably the Tanáwal beds re-appear to the west in the Afridi mountains, and they most likely occur also along the flanks of the mountains in Yusufzai north of the Peshâwar valley. The newer rocks undergo similar interruptions. The Mianjáni peak (9,793 feet), S.S.E. from Tandiáni, is of Attock slate, but south of it again the Mochpura mountain (9,232 feet), north of Murree, is of nummulitic limestone with occasional outcrops of the jurassic and triassic strata; and these three formations, the nummulitic limestone still predominating, form the broad band of hills to the south-west, terminating in the Margála range. Through the Margála pass there is a narrow continuous outcrop connecting this range with the Chitapahár range, south of the Attock hills, and passing westwards into the range of the Kotal pass, north of Kohát. They probably extend far into the Afridi country. Some considerable hills of the nummulitic and mesozoic rocks occur, isolated in the plain south and west of Hassan Abdal.

The Peshâwar depression.

The large basin of depression, the greater part of which is known as the Peshâwar valley, is a remarkable feature the origin of which is not very clear. Its outline, as already indicated, is very irregular, long spurs or ranges stretching into it from the surrounding mountains as if it had formerly been produced by the erosion of the rivers that have subsequently filled it up again. Considering its position, and the extent of hilly ground, sixty miles in a direct line along the gorge of the Indus, by which it is separated from the great plains of the Punjab, its low elevation is remarkable, only 1,100 feet at the trigonometrical base-line on the Chach plain close to the Indus, and 1,250 feet at Peshâwar. The present surface is largely made up of diluvial gravels from the hills around, so there is a considerable rise to the margin of the area; at Hassan Abdal the level is 1,400 feet, and at the Margála pass 1,700, which is the level of the Potwar plateau at Rawalpindi. Mr. Theobald (Records, G. S. I., XIII, p. 230) has given fair evidence to show that the Indus was formerly confluent with the Haro river near the point of the Gandgarh range, and that its present junction with the Kabul river where it enters the gorge at Attock is of recent date. Some interesting information regarding the depth and composition of these deposits has recently (1883) been furnished from a boring that was made in the futile expectation to find the nummulitic coal in a more favourable condition beneath the alluvium than in the Chitapahár hills close by. A hole was put down in the bank of the Haro, 70 feet below the level of the plain, at two miles from the Indus and about one mile from the nearest point of the hills. It was stopped at a depth of 252′ 6″ in consolidated sand, but from 121′ to 233′ the section was all in yellow and blue clay. The position, being close to the outlet of the basin, shows how steep its lower rock margin must be. The excavation of this basin may well have been effected in tertiary times, but it is probable that considerable depression has occurred consequent on the accumulation of deposits.

The Afghan Region.
The tertiary basin.

We have already seen the lower tertiary rocks as massive nummulitic limestone taking a conspicuous place in the higher hills of Hazára between Murree and Abbottabad in parallel sequence with upper mesozoic strata. There is however a very marked feature, probably involving a considerable fault, separating that ground from the exculsively tertiary area to the south; and it is continuous with the main tertiary boundary of the sub-Himalayan region. It is well marked west of Murree and along the base of the Margála and Chitapahár ranges, and Mr. Wynne has traced it even beyond the Indus, north of Kohát. The tertiaries in the sub-Himalaya appear as a zone fringing the mountains and passing under the alluvium of the plains, but from the Jhelum to beyond the Indus at Sheikh Budin they lie in a basin, between the old rocks of the Salt Range and the Afghán mountain region. It cannot be asserted that the Salt Range was an original limit of deposition for these deposits. There is indeed positive proof that it was not so absolutely, for in several places, as at the Chambal ridge (east end of the range) and west of the Indus near Kálábágh, upper tertiary strata occur on the outer base of the range. But that it was so, at least partially, especially for the lower tertiaries and for the east end of the range, is demonstrable. The nummulitic series here is scarcely a twentieth of its thickness in the northern outcrops, and there is an abrupt passage, with something like an erosion unconformity, from the nummulitic limestone to mammaliferous Siwálik clays and sandstones, instead of the graduated transition that marks this horizon in the mountain region. A question of some little interest has been raised as to the correlation of the nummulitic beds of the sub-Himalaya and of the trans-Jhelum sections. The massive sandstones and red clays forming the ridge on which Murree is built are underlaid on the west by finer variegated clays with earthy nummulitic limestone: the section is exactly like those in the Sirmur area south of Simla, the upper beds corresponding with the Dagshai group and the lower ones with those of Subáthu; and those particular beds close to Murree are undoubtedly at the top of the nummulitic series and probably higher than the massive limestone of the mountains to the west. From this section Mr. Wynne in all his papers on these rocks has treated the Subáthú group as a distinct upper member of the nummulitic series. But this name had been already appropriated to the whole nummulitic series in the sub-Himalayan region, and it is almost certain that the bottom beds of Subáthú are on the very lowest nummulitic horizon. The presumption is that the strong limestones of the Hazára hills and of Kohát have taken the place of the brown estuarine clays that so prevail in the sub-Himalayan region. From Murree to the south-east there is an ascending section, though with faulted repetitions, through an enormous thickness of middle and upper tertiary deposits, precisely resembling and actually continuous with those of the sub-Himalayan zone, but in the Jhelum and Rawalpindi districts they form a wide synclinal basin, with numerous secondary flexures. The whole is now plained down into a broad upland, known as the Potwar, much intersected in all directions by deep ravines eroded in the soft Siwálik strata. In

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The Suleman Range.
The tertiary basin.

Mr. Lydekke's Synopsis of the fossil vertebrates of India (Records, G. S. I., XVI, 2) the indication "Punjab" refers mostly to this ground where some rich collections of bones have been made, chiefly in the south-east part of the district, as about Asnot, west of Mount Tilla. Numerous fossils of a lower horizon have been found south of Kushalgarh, on the Indus. West of the Indus, in Kohát, the nummulitic group is more broadly exposed, and is here associated with, or at least immediately overlies, immense deposits of rock salt described in a previous section. The east-west strike is still steady here, but at the Kurram river it seems to change abruptly into the north-south strike of the Sulemán axis, and here, on the right bank of the river opposite Thul, Mr. Wynne observed the lower tertiaries to be extensively invaded by basic trappean rocks, a condition almost unknown throughout the whole tertiary region to the east.

SECTION H.—THE SULEMAN RANGE.

The Sulemán Range.

It is only as a background that the Sulemán range can be introduced into a sketch of Punjab geology, for from Bannu southwards the frontier lies at the base of the hills, on the gravel slopes bordering the alluvial plains of the Indus, with the exception of a small slice of the Mari and Bugti hills west of Rajanpur in the Dera Gházi Khan district. The range is but the eastern edge of an immense tract of mountainous country stretching indefinitely westwards, and the drainage for a considerable distance passes through the Sulemán ridge into India. In the regions previously described the older rocks are predominant, but the region of which the Sulemán is only a fragment, including Southern Afghánistán, all Bilúchistán and the greater part of Persia, is almost exclusively made up of tertiary and cretaceous deposits with eruptive rocks of the same ages.

It is only of the southern part of the Sulemán that we have any accurate geological knowledge, as recently described by Mr. W. T. Blanford (Memoirs, G. S. I., Vol. XX). He gives the following list of the rocks exposed :—

4. SIWALIK, or Manchhar (of Sind) :
    - Upper (*pliocene*) : conglomerates overlying sandstones and clays with conglomeratic bands ; 2,500 feet.
    - Lower (*upper miocene*) : sandstones, clays, marls, bone beds, &c. ; 5,000 feet.
3. NARI (*miocene*) : sandstones, clays, &c. ; 2,000 feet.
2. EOCENE :
    - Upper : olive clays, shales, sandstones, &c., with a few thin bands of nummulitic limestone and occasional coaly beds ; 7,000 to 9,000 feet.
    - Lower : coarse brown sandstone with a band of limestone breccia ; 1,000 feet.
1. CRETACEOUS :
    1. Hard whitish sandstone grit ; 1,500 feet.
    2. Dark grey limestone passing down into limestone shales ; 1,000 feet seen.

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The Suleman Range.

The Sulemán Range.

There is considerable difference between this section and that known in Sind. The whole Gáj group (a marine formation some 1,500 feet thick) is wanting between the Nari and Siwálik horizons, as is also the oligocene marine limestone at the base of the Nari group, thus bringing the upper tertiary series here into closer correspondence with that found in the Potwar and the sub-Himalaya as exclusively of fresh water or subærial formation. There is also a remarkable deficiency of limestone in the eocene series of the southern Sulemán as compared with the sections both in Sind and in the Upper Punjab. No unconformity has been detected throughout this enormous sequence of strata, notwithstanding the apparent gaps; but it is clear that disturbance commenced long before the deposition of the newer beds which now fully partake in that disturbance, for the top conglomerates, which are now themselves often tilted up to the vertical, are formed of the *debris* of the rocks of the main ridge, which must therefore have been partly upraised and undergoing denudation in the Siwálik period. Similar evidence of the slow process of mountain formation has previously been quoted from the sub-Himalayan region. The Sulemán ridge is an anticlinal flexure, only greater than those on either side of it, whereby the older (cretaceous) rocks are brought up and exposed by denudation along the crest. From the evidence of stones in the stream beds it has been asserted that older formations come to the surface at the north end of the range, as is not at all unlikely. The Siwálik rocks only are found along the outer margin next the plains.

Mr. Griesbach, who accompanied the expedition to the Takht-i-Sulemán in December, 1883, has given an outline of the geology, in which there are some striking differences from the section described by Mr. Blanford 40 miles to the south. The whole crest of the range at and about the Takht is formed of pale marine coral limestone many hundred feet in thickness, resting on a sandstone which Mr. Griesbach identifies with the cretaceous sandstone of Mr. Blanford's section, and he considers the limestone also to belong to that epoch. Another striking contrast is that the Siwáliks are represented as resting completely unconformable on the edges of lower eocene strata.

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The Plains.

Effect of the upheaval which raised the Siwáliks upon the underlying deposits of the plains.

to the south of the actual boundary depends upon the view taken of the process of disturbance. It is difficult to resist the *primâ facie* impression from the sight of an immense thickness of stratified rock turned up on end that great violence must have attended such results, and hence that the effects must have extended to far beyond the point where such intensity is exhibited. It was upon such natural impressions that the cataclysmal theories of the early geologists were founded. In the present case, the plausible supposition from such a point of view would be that an elevation of the Himalayan area coincident with the contortions of the Siwálik strata had first resulted in a great valley of erosion from the mountains to the sea, forming a clean-swept basin for the deposits which now form the plains.

Practical importance of the question.

To give meaning to this seemingly useless discussion it may be well to point out that it forms the only rational approach to the practical question often asked—where in the plains and at what depth would there be a prospect of success for an artesian boring. If the supposition just noticed might be counted upon, a very favourable answer could be given to this question. The base of the deposits would then be everywhere within reach; that base would generally consist of coarser materials, such as would form a capacious water-stratum; and it would be in continuous connexion with the present upper zone of gravel beds at the foot of the hills, where copious absorption of water occurs.

Siwálik upheaval probably very limited in its effects.

Careful observation and reflection are, however, against that *primâ facie* supposition. It will be shown that before the disturbance of the Siwálik rocks (*i.e.*, during the Siwálik period) the Himalayan rivers, great and small, flowed just where they now do in the mountains; so that there is nothing to support the supposition that any great elevation or violent movement of any kind accompanied the disturbance of the Siwálik rocks; for they probably were tilted up so slowly that the main rivers could *pari passu* erode their gorges across the rising strata. Another fact of corresponding import is found in the form taken by the Siwálik strata under disturbance. The *dúns*, or longitudinal valleys occurring so constantly inside the Siwálik ranges, are generally formed of the topmost Siwálik strata in a more or less horizontal condition, rising by a gradual increase of dip to form the range outside the *dún*, while on the inner side they either abut abruptly against the rocks of the inner range, or else are bent up sharply to form that range. Such a feature strongly suggests the probability that the final limit of the disturbance may be no less abruptly marked; so that beyond the extreme verge of the vertical Siwálik strata these same strata may have remained permanently in their original gentle slope of deposition, and would thus be in conformable sequence with the most recent deposits of the plains within a very short distance of the hills. It is independently intelligible that the slow compressing force to which the bending of the strata and the consequent rise of the hills were due would expend itself to the utmost on each flexure before giving rise to a new one.

Such a process would of course involve great erosion of the Siwálik strata in the immediate region of upheaval; and there is

The Plains.

Siwálik upheaval probably very limited in its effects.

abundant evidence of this, not only in the river gorges and the deep ravines of the minor streams, but along the whole outer edge of the hills, where, as a rule, the uppermost gravel beds of the plains rest upon the edges of low Siwálik strata near the axis of the flexure, the whole of the outer and steeper side of which has been removed. Under the supposed conditions of disturbance this denudation would not have reached far; so that within a short distance there might be completely conformable sequence between the Siwálik deposits and those of the actual plains.

Artesian boring at Ambala.

One important direct observation has been made upon the underground constitution of the plains, in the boring for an artesian spring at Ambala, to a depth of 700 feet. No gravel bed or other water stratum was met with, and the boring ended in stiff clay. If this section could be taken as representative, it would be conclusive evidence against the supposition of these deposits lying in a simple post-Siwálik basin of erosion; for the bottom of such a basin must at Ambala be within a much less depth than 700 feet, and the basal beds in such a basin must as a rule be coarse, porous, and water bearing. It is easy to explain a possible exception to this rule; and Ambala is just in the position where such an exception would be most likely to occur. It is about 20 miles from the foot of the hills, and this is beyond the distance to which gravel is now swept by the small streams and the rain-wash on the steeper slopes near the hills. It is only within the range of the great rivers, in the deeper parts of the supposed basin of erosion, that coarse deposits must occur somewhere in almost every section, especially at or near the base; and in river-formed deposits such as these, the range of the great rivers embraces in time more or less the whole area. Ambala, about midway between the Jumna and the Sutlej, and so near the hills, is just in the position most likely to escape that influence, as the whole growth of deposits might be directly from the hills, or by overflow of finer sediment from the main rivers. In this way there might be nothing there to mark the bottom of the basin or surface of erosion in so small a section as that given by a boring; and thus the passage from the recent plains deposits into beds of such similar composition as are those of the upper Siwáliks would not be noticed. It can, however, be affirmed that the boring did not reach beds that had undergone any considerable disturbance, for the frequency of alternation of beds in the lower part of the boring was as great as in the upper part, whereas a very moderate tilting of the lower beds would have given a perceptible apparent thickening of the several strata passed through by a vertical boring.

Inconclusive nature of the results.

Changes of level consequent upon transfer of matter from the mountains to the plains disturbing local equilibrium.

There is yet to be taken into account a consideration of great weight in this discussion. It was long ago suggested by Herschell, in seeking for a prime mover of the forces by which crust movements are effected, that the familiar process of denudation by the continual removal of matter from steep elevated tracts and the deposition of it in adjoining low ground evidently disturbs the equilibrium of strain beneath those areas, causing a tendency to elevation in the former and to depression in the latter. Recent researches upon the nature of the earth's rigidity entirely confirm